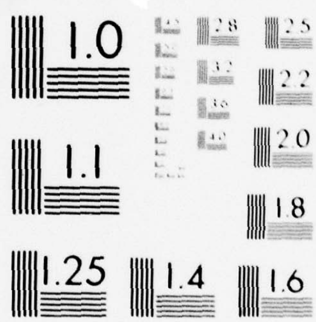
AD-A068 315 INSTITUTE FOR DEFENSE ANALYSES ARLINGTON VA SYSTEMS E--ETC F/G 17/4
ELECTRONIC WARFARE JOINT TEST AND EVALUATION: DESIGN OF A SIMUL--E
AUG 74 S L WALLER, J H DANIEL, R M SHAW DAHC15-73-C-0200

UNCLASSIFIED P-1042 IDA/HQ-74-16452 NL

| OF |

AD
A068315

END
DATE
FILMED
6-79
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

AD-E500 039

UNCLASSIFIED

LEVEL III

Paper P-1042

AD A068315

ELECTRONIC WARFARE JOINT TEST AND EVALUATION:

Design Of A Simulation Program For Determining Engagement Kill Probabilities Using The AFEWES Facility

August 1974

S. L. Waller, *Project Leader*

Committee Members:

J. H. Daniel, Chairman
R. M. Shaw, Joint Test Director Staff
D. R. Tipton, General Dynamics, Ft. Worth

This paper has been prepared by the Systems Evaluation Division of the Institute for Defense Analyses in response to the Weapons Systems Evaluation Group Task Order DAHC15 73 C 0200 T-180, dated 17 March 1972.

In the work under this Task Order, the Institute has been assisted by military personnel assigned by WSEG.

IDA
INSTITUTE FOR DEFENSE ANALYSES
SYSTEMS EVALUATION DIVISION

IDA Log. No. HQ 74-16452
Copy 91 of 95 copies

UNCLASSIFIED

79 04 06 056

~~This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Director of Defense Research and Engineering, Washington, D.C. 20301.~~

~~Each transmittal of this document outside the Department of Defense must have prior approval of the Director of Defense Research and Engineering, Washington, D.C. 20301.~~

~~Further reproduction of this document is prohibited without prior approval of the Director of Defense Research and Engineering, Washington, D.C. 20301.~~

Information and events after August 15, 1974, are not reflected in this report.

Approved for public release;
distribution unlimited

UNCLASSIFIED

Paper P-1042

ELECTRONIC WARFARE JOINT TEST AND EVALUATION:

Design Of A Simulation Program For Determining Engagement Kill Probabilities Using The AFEWES Facility

August 1974

Information and events after August 15, 1974, are not reflected in this report.

S. L. Waller, *Project Leader*

Committee Members:

J. H. Daniel, Chairman
R. M. Shaw, Joint Test Director Staff
D. R. Tipton, General Dynamics, Ft. Worth

This paper has been prepared by the Systems Evaluation Division of the Institute for Defense Analyses in response to the Weapons Systems Evaluation Group Task Order DAHC15 73 C 0200 T-180, dated 17 March 1972.

In the work under this Task Order, the Institute has been assisted by military personnel assigned by WSEG.

IDA

INSTITUTE FOR DEFENSE ANALYSES
SYSTEMS EVALUATION DIVISION
400 Army-Navy Drive, Arlington, Virginia 22202

DAHC15 73 C 0200
T-180

UNCLASSIFIED

PREFACE

The purpose of this report is to present the design for a simulation program using the Air Force Electronic Warfare Evaluation Simulator (AFEWES) facility at General Dynamics, Fort Worth, to obtain estimates of aircraft attrition resulting from SAM or AAA engagements over the range of conditions experienced in the Phase II EW Joint Test. WSEG/IDA was assigned responsibility for designing the AFEWES simulation program by letter from Lt. Gen. Alfred D. Starbird, USA (ret), DDT&E to Lt. Gen. Glenn A. Kent, USAF, Director WSEG, dated 7 August 1973 with enclosed letter to Admiral Martin D. Carmody, USN, EW Joint Test Director, dated 19 July 1973. The letter to Admiral Carmody assigned responsibility to the EW Joint Test Director for execution of the simulation design at General Dynamics. The results will be used both by the Test Director and by WSEG/IDA in their separate evaluations.

(cont on p. 2)

In order for WSEG/IDA to develop a design for a simulation program that would be compatible with the AFEWES facilities available at General Dynamics and acceptable for execution by the Test Director, it was decided by WSEG/IDA to set up a working committee comprised of representatives of the Test Director, General Dynamics, and IDA. The objective of the committee was to develop a plan for the use of AFEWES which would meet the requirements of the EW Joint Test and Evaluation Program within the monetary and time constraints of the program. This report presents the results of the efforts of this committee.

In some cases, alternative procedures within the general approach for obtaining the required P_k estimates are presented. The decisions as to which of these alternatives can best be used to obtain the desired attrition estimates will depend largely on the results of the pre-test AFEWES concept-validation program which is currently underway.

CONTENTS

APPENDICES

Chapter I

INTRODUCTION

(cont fr p. iii)

The overall objectives, test design, and evaluation approach for the Phase II Electronic Warfare Joint Test (EWJT) have been described previously.[1] The evaluation will make use of the following types of simulations:

(1) Simulation of representative engagements to obtain kill probabilities of SAMs and AAA versus aircraft, and ARMs versus radars, using the initial conditions of the engagements (as established by the tests) as inputs. and

(2) Simulation of radar detection and weapon assignment and control functions of the integrated air defense system (IADS), using test-determined parameters, plus the kill probabilities determined in (1), as inputs.

The overall relationships between test data and simulations are shown in Figure 1.

The engagement simulations of (1) are to be carried out primarily with the Air Force EWES simulation facility at General Dynamics, Ft. Worth, and with Navy ARM trajectory simulators at the Naval Weapons Center, China Lake. The command and control simulations of (2) are to be carried out with the digital TADBM simulator--a modification of the Air Force TDM by General Dynamics--now installed at IDA. TADBM is not

[1] WSEG Report 223, Electronic Warfare Joint Test and Evaluation: Design of the Phase II Electronic Warfare Joint Test, March 1974, Volume I (CONFIDENTIAL), and Volume II, Appendices (SECRET).

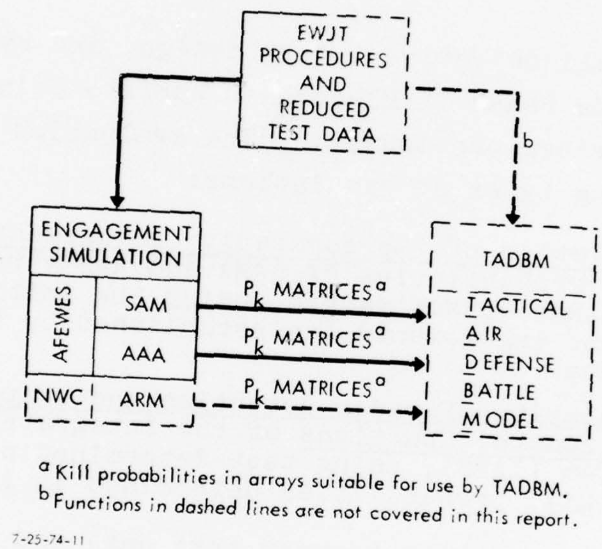


Figure 1 (U) RELATIONSHIP BETWEEN ELECTRONIC WARFARE JOINT TESTS (EWJT) AND SIMULATIONS SUPPORTING THEIR EVALUATION

designed for simulation of overall command and control and battle events in real time with men-in-the-loop, as is AFEWES for simulation of individual engagements. Hence, TADBM must be calibrated--i.e., some input parameters (such as typical time intervals between certain events) must be determined by the results of operational tests (or more detailed simulations) of relevant modes of a representative command and control system. TADBM then makes use of kill probabilities determined by AFEWES (or other engagement simulators) to provide overall attrition.

This committee report is concerned primarily with the engagement simulations of (1), above.[1] These have as their objectives the determination of engagement miss distances and associated kill probabilities which are:

(1) Representative of the variety of engagement conditions realized in the tests. Such kill probabilities are for use in level 2 evaluation, i.e., analysis of the Phase II test missions in terms of cumulative kill probabilities, ignoring the effects on successive engagements of possible kills in previous engagements.

(2) Representative of engagement conditions defined by the TADBM simulator in further analysis of the test missions (level 3 evaluation) to determine the effects of removal of weapon systems which would have been killed in the tests, had missiles actually been launched or projectiles fired.

Although the Joint Test Director and WSEG/IDA are to make separate post-test evaluations, the extensive engagement simulations required to extend test results to kill probabilities, like the test data itself, must serve the needs of both. Thus, it is the purpose of this committee report to present the following in some detail:

(1) The informally coordinated plans and procedures which are being worked out between the Test Director and IDA/WSEG to accomplish the objectives of the engage-

[1]Excluding engagements of ARMs vs. radars, which are not covered in this report.

ment simulations (as stated in the previous paragraph) within the allowed constraints of time and money.

(2) Resulting data requirements, to insure that either the data will be available, or that alternative procedures can be used.

Primary emphasis in this report is placed on the SAM vs. aircraft engagement. To answer some of the unresolved issues, the Test Director is initiating a series of pre-test simulations with AFEWES.[1] These are necessary to permit simplifying and expediting post-test simulations. ECM-radar features of AAA vs. aircraft engagements are somewhat analogous to those of SAM vs. aircraft engagements. There are no plans to use optical tracking with SAMs or AAA in either the tests or the simulations. Strike aircraft will be constrained to altitudes no less than 8,000-9,000 feet except when simulating weapons delivery on the two target areas; this further limits engagement opportunities for the relatively short-ranged AAA. Trajectory and kill-probability simulations involved in the ARM vs. radar engagements (not discussed in this report) are expected to be relatively straightforward and inexpensive.

At a meeting at IDA on 11 July 1974 between representatives of WSEG/IDA, the Joint Test Director, and General Dynamics, IDA representatives indicated requirements for AFEWES-derived P_K matrices,[2] based on test data, to be completed by 1 February and 1 March 1975, as shown in Table 1, in order for the WSEG/IDA evaluation to be accomplished in time for delivery of the final report to DDR&E by 30 June 1975. To meet the 1 February and 1 March dates would seem to require an initial selection of

[1]Simulation runs are scheduled to begin around 12 August 1974. About $70,000 has been allocated for this pre-test effort (including possible AAA and ARM simulations). The allocation for post-test simulations is about $200,000.

[2]The term "P_K matrix" is used to indicate an array (for a given target altitude) in which P_Ks are associated with selected points (or areas) in downrange and offset coordinates.

Table 1 (U). SCHEDULE OF EVENTS APPROPRIATE TO PRODUCTION OF P_k MATRICES FOR USE IN THE IDA/WSEG EVALUATION

Start of Test	7 October 74
• Reduced-data package from 1st days' test strikes delivered for checkout	11 October 74
• Delivery of reduced-data package from 1st 2 weeks testing (1st complete replication) completed	14 November 74
End of Test	15 November 74
• Delivery of reduced-data packages from all test strikes (3 replications) completed	27 December 74
• AFEWES runs for Air Force strikes completed, P_k matrices delivered to IDA/WSEG.	1 February 75
• P_k matrices for Navy strikes delivered to IDA/WSEG.	1 March 75
• IDA/WSEG evaluation report delivered to DDR&E	30 June 75

test engagement conditions for AFEWES runs based on only the first of three test replications. Whether this would indeed be the most expeditious way of proceeding (costs of additional AFEWES setups as well as runs could be involved) can be decided later with benefit of results and experience obtained from the pre-test simulations. In general, where faced with a choice of alternative procedures for employing AFEWES which it believes can be made with greater confidence at a later date without jeopardizing schedules, the committee has chosen to present both alternatives in this report.

Chapter II

SUMMARY

A. GENERAL APPROACH

The flow diagram of Figure 2 summarizes the general approach adopted to obtain kill probabilities for the types of engagements initiated in Phase II EWJT. Crucial to expeditious accomplishment of this task are:

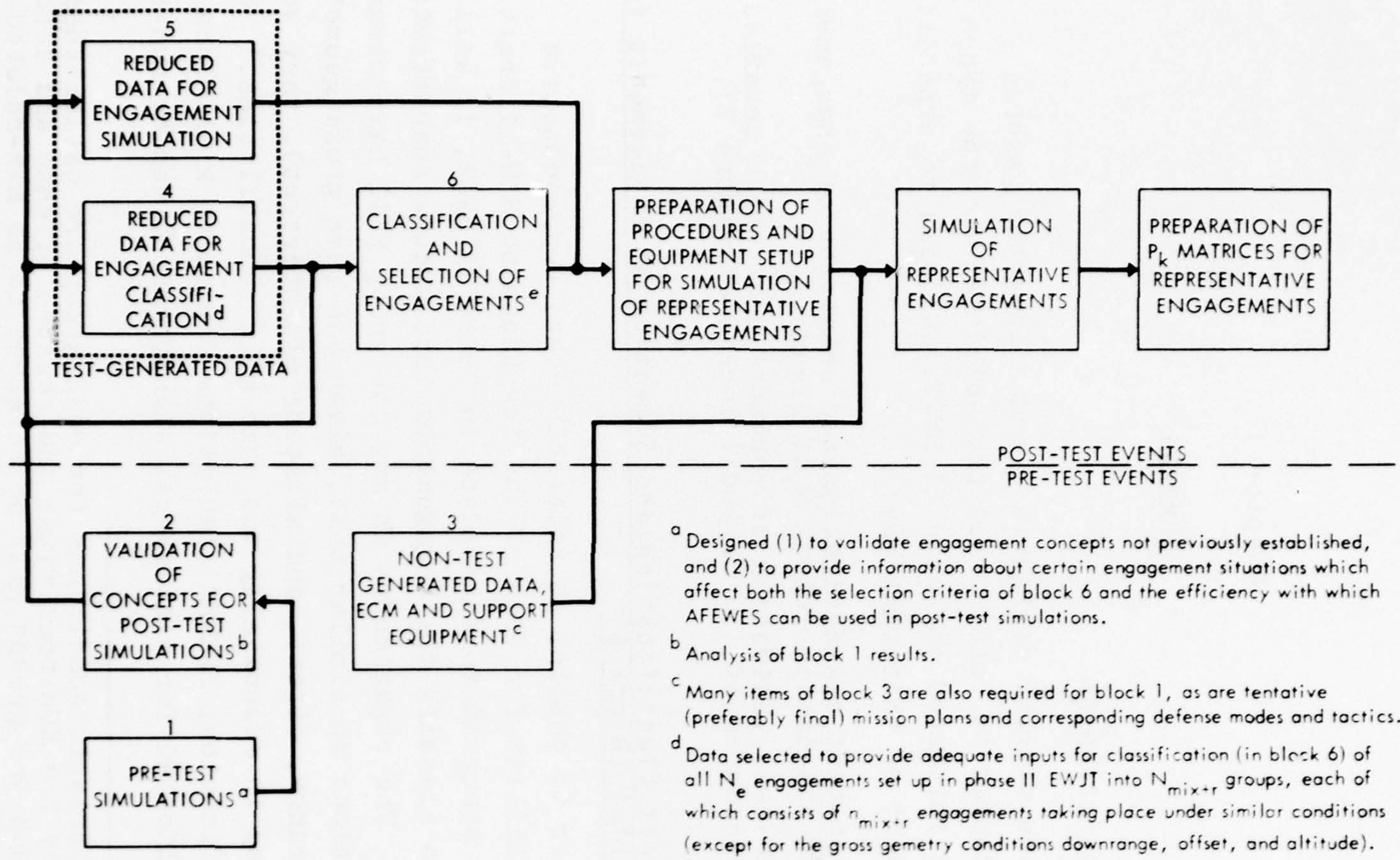
(1) Post-test classification and selection of engagements for simulation (block 6 of Figure 2).

(2) Pre-test validation of concepts upon which detailed procedures of (1) depend (block 2 of Figure 2).

1. Post-test Classification and Selection of Engagements for Simulation (Block 6)

In order to obtain, at tolerable cost, representative kill probabilities for each of the few thousand SAM-aircraft engagements expected to take place in Phase II EWJT, it will be necessary to classify the engagements into groups characterized as follows: The engagements in any one group will have occurred under conditions so similar that, given the same gross geometry (i.e., downrange, offset, and altitude of intercept), they would have resulted in essentially the same kill probabilities.[1] With such classification, AFEWES simulations for salvo kill probability (replicated for statistical significance) can be run for

[1] The characteristic conditions for each group are established primarily by the ECM test mixes and related offense and defense tactics; thus the groups will be referred to as mix-related groups.



[a] Designed (1) to validate engagement concepts not previously established, and (2) to provide information about certain engagement situations which affect both the selection criteria of block 6 and the efficiency with which AFEWES can be used in post-test simulations.

[b] Analysis of block 1 results.

[c] Many items of block 3 are also required for block 1, as are tentative (preferably final) mission plans and corresponding defense modes and tactics.

[d] Data selected to provide adequate inputs for classification (in block 6) of all N_e engagements set up in phase II EWJT into N_{mix+r} groups, each of which consists of n_{mix+r} engagements taking place under similar conditions (except for the gross gemetry conditions downrange, offset, and altitude). $N_e = N_{mix+r}\bar{n}_{mix+r}$.

[e] So that only a few simulation runs are required for each of the N_{mix+r} groups.

8-12-74-4

Figure 2 (U). FLOW DIAGRAM OF SEQUENCE FOR OBTAINING KILL PROBABILITIES REPRESENTATIVE OF ENGAGEMENTS INITIATED IN PHASE II ELECTRONIC WARFARE JOINT TESTS

the selected test conditions of each mix-related group rather than for individual engagements.

Based on the test design, on assumed mission plans and offense-defense tactics and modes of operation, and on possible simplifications to be verified in pre-test simulations, it appears that fewer than 100 mix-related groups will require post-test simulation (Chapter IV, Section A1).[1] For each group, a unique P_k matrix can be determined which gives P_ks vs. the targeted aircraft as a function of its position in a two-dimensional grid in downrange and offset coordinates (for a given altitude).

2. Role of Pre-test Simulations (Blocks 1 and 2)

The pre-test simulations are required to:

(1) Determine whether some expected variations in mix-related conditions actually require classification into different groups.

(2) Verify that P_ks for some groups can be simply derived from those of more basic groups without requiring simulation.

(3) Quantify the increased efficiency obtainable with certain AFEWES runs by employing off-line processing of tracking-error tapes.

Some of the mix-related groups may contain a large number of completed test engagements (i.e., launches followed by single-salvo intercepts) widely dispersed in gross geometry (downrange, offset, and altitude); other groups may have engagements with many salvo intercepts concentrated in only a few coordinate regions; still others may have only a few completed engagements. For groups having many single-salvo intercepts along the downrange coordinate at a given offset and altitude, AFEWES can be used more efficiently by recording tracking-error

[1]This is, of course, a rough estimate which cannot be significantly refined until mission plans and tactics become firm, and the findings of AFEWES pre-test simulations are available.

(TE) tapes for off-line processing.[1] Pre-test simulations will help establish the magnitude of this efficiency gain, as well as provide an indication of how rapidly P_k varies with group gross geometry. Both factors are involved in determining the cost of "complete-grid" P_k matrices.

Complete-grid P_k matrices would give P_ks for all possible engagements in a group. This is, of course, more than needed for the evaluation of test results without removal of weapons systems which would have been killed in the test (level 2 evaluation), but would insure that few if any additional AFEWES simulations would have to be made for new gross geometry situations which might arise as a result of such removal (level 3 evaluation). A complete-grid matrix would also be advantageous for the basic on-board ECM group, since pre-test simulations are expected to show that its P_k matrix can be used without further simulation to obtain P_ks in certain other groups. Section B of Chapter IV discusses further possible applications of pre-test simulations, and presents the limited program now planned (Table 6).

B. PROCEDURES FOR POST-TEST SIMULATION

The presently indicated post-test simulation procedures, starting upon receipt of reduced test data, are as follows:

(1) Classification of test engagements into mix-related groups.

(2) Construction, for each group, of downrange-offset diagrams (for the appropriate altitude region or regions) of the mean position of intercepts of each salvo.

(3) Selection of groups requiring simulation, in view of the findings of the pre-test simulations, and considering unanticipated sub-groups that may have arisen from the tests.

---

[1]This procedure cannot be used with jamming directed against missile-tracking (MTJ). It is not the procedure which has normally been used with AFEWES.

(4) Division of selected groups into (1) those for which simulation for complete-grid P_k matrices is most appropriate, and (2) those for which simulation of partial grids (or only the salvo intercepts observed in the tests) is most appropriate. Determination of whether normal AFEWES runs (rather than TE tape runs) would be more suitable for the latter.

(5) Preparation of detailed test specifications for AFEWES simulation runs for the chosen groups.

(6) Execution of simulation runs in order promoting greatest efficiency (least set-up time, etc.).

(7) Compilation of P_k matrices, including specification of pertinent group conditions required for ready use by the digital TADBM (Tactical Air Defense Battle Model).

Items (5) and (6) are not different in concept from the detailed and complex procedures and operations routinely carried out by General Dynamics personnel. TADBM has been designed with flexibility to accommodate item (7). Hence, this report emphasizes items (1)-(4). Detailed discussions of these items are given in Section C of Chapter III and Section A of Chapter IV.

After results of pre-test simulations are available, the method of mix-related grouping illustrated in Table 3 of Chapter IV should be revised in time to check-out the procedures of items (1)-(4) with reduced data from the full-system checkout missions which are to be flown just prior to the tests.

C. DATA REQUIREMENTS

The type data not generated in test activities (and the support equipment) required for Phase II post-test AFEWES simulations is listed in Appendix A. Appendix B gives a similar listing of the test-generated data required for such simulations. The more limited test data required for the classification and selection purposes of items (1)-(4), above, are presented in more detail in Section A2 of Chapter IV.

D. CONTINGENCY PROCEDURES FOR POST-TEST SIMULATIONS

Unlike the procedures involved in items (5) and (6) of Section C above, those involved in items (1)-(4) have never been carried out. Thus, problems may be expected, and in view of the tight schedule,[1] consideration must continue to be devoted to simplified and possible contingency procedures.[2] Among such are the following:

(1) Use of pre-test simulation results whose engagement conditions match those realized in the tests.

(2) More frequent use of partially-filled rather than completely-filled grids for P_k matrices, or use of coarser grids.

(3) Judicious use of fewer mix-related groups.

(4) More frequent use of scaling or other approximations between or within groups.

(5) Use of other simulation results whose engagement conditions match those of the tests, or whose results can be related to those for the test conditions by simple transformations.

---

[1]See Table 1 of Chapter I. The analogous simulations for AAA have to be carried out using the same AFEWES facilities.

[2]Note, for possible analogy, how many desirable but less essential items for pre-test simulation (Section B2, Chapter IV) have had to be excluded from the tentative list (Table 6) which now appears doable with the money and time available.

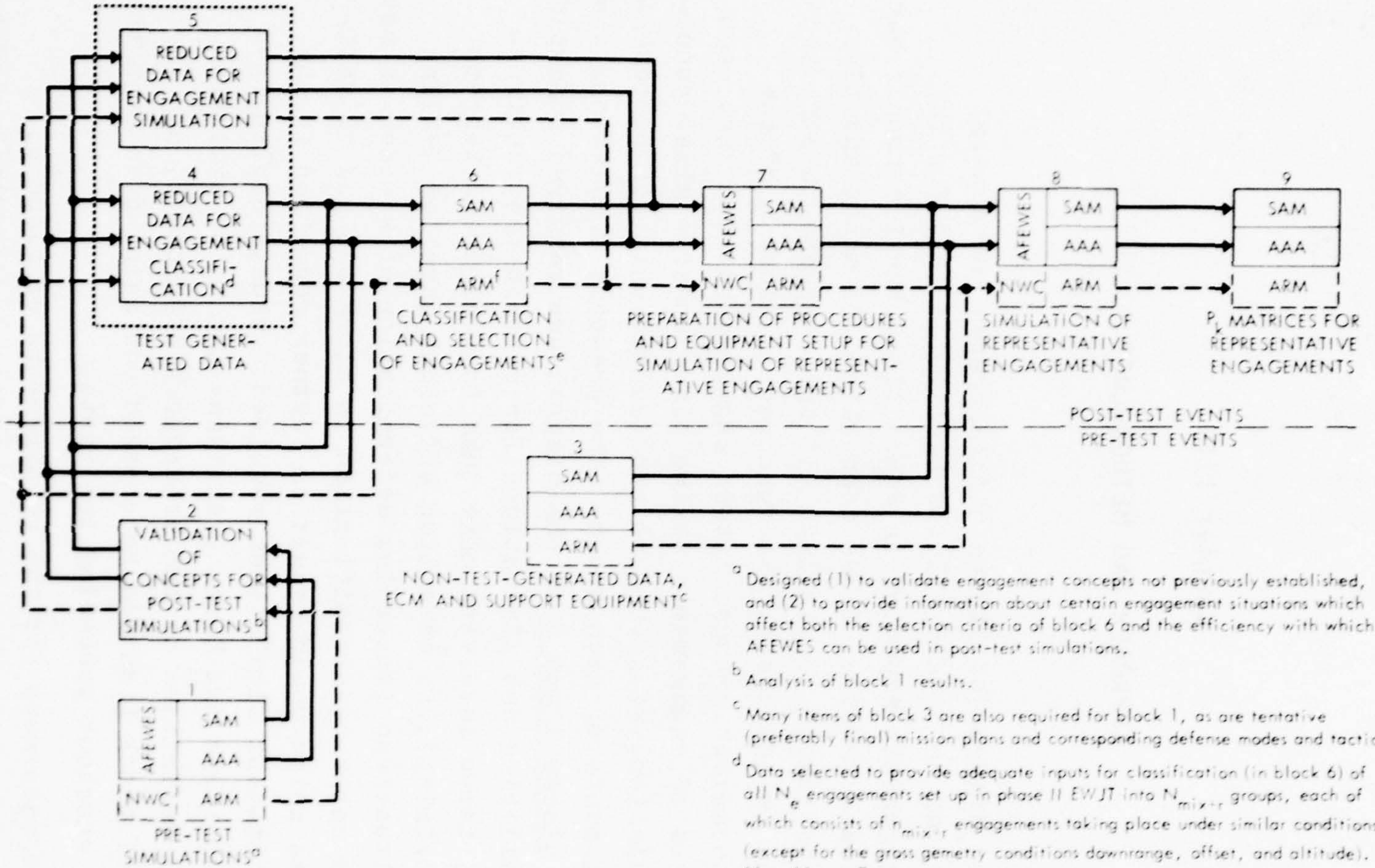
Chapter III

APPROACH AND METHODOLOGY

A. GENERAL

The flow diagram of Figure 3 illustrates the general approach adopted to obtain kill probabilities (P_K) for the types of engagements expected in Phase II of the Electronic Warfare Joint Tests (EWJT). Since constraints of money and time make it impracticable to simulate all the engagements expected to take place in the tests, the function of block 6 of the diagram is to select groups of test engagements such that each group consists of engagements taking place under similar conditions. Simulations will then be carried out only for representative engagements of each group. The pre-test simulations and analyses of blocks 1 and 2 of the diagram are required to explore AFEWES capabilities and limitations for certain test environments (e.g., those involving more than four aircraft targets in close proximity), to establish efficient ways for dealing with such situations (including determination of whether or not they require separate classification in block 6), and to validate concepts which could result in further reduction in the number of post-test simulations required. Thus, results from block 1 simulations and block 2 analyses should be available before final definition of the procedures of block 6, and the procedures of block 6 should be checked out using data from the full system checkout preceding the tests.

Block 4 data must fit the requirements of block 6; blocks 3 and 5 supply supporting facilities and additional data



[a] Designed (1) to validate engagement concepts not previously established, and (2) to provide information about certain engagement situations which affect both the selection criteria of block 6 and the efficiency with which AFEWES can be used in post-test simulations.

[b] Analysis of block 1 results.

[c] Many items of block 3 are also required for block 1, as are tentative (preferably final) mission plans and corresponding defense modes and tactics.

[d] Data selected to provide adequate inputs for classification (in block 6) of all N_e engagements set up in phase II EWJT into $N_{mix \cdot r}$ groups, each of which consists of $n_{mix \cdot r}$ engagements taking place under similar conditions (except for the gross gemetry conditions downrange, offset, and altitude). $N_e = N_{mix \cdot r} \bar{n}_{mix \cdot r}$.

[e] So that only a few simulation runs are required for each of the $N_{mix \cdot r}$ groups.

[f] Dashed-line functions are not considered in this report.

Figure 3 (U). FLOW DIAGRAM OF APPROACH FOR OBTAINING KILL PROBABILITIES REPRESENTATIVE OF ENGAGEMENTS INITIATED IN PHASE II ELECTRONIC WARFARE JOINT TESTS

for the definition (block 7) of test conditions for the engagement groups selected by block 6 and simulated in block 8; block 9 forms P_k matrices from the results. Thus, the methodologies and procedures which are unique to the type and scale of simulation effort required for levels 2 and 3 evaluation of the Phase II tests are associated primarily with functions of the key blocks 1 and 2, and 6.

Actually, as described above, an iterative process not indicated in Figure 3 takes place between blocks 1 and 2 and block 6. Thus classification in block 6, which is initially based on mission plans for the tests, defines or limits the scope of the pre-tests simulations and analyses of blocks 1 and 2. The latter then better define the classifications in block 6 so as to reduce the number of selections required for post-test simulation in block 8, either by determining that some potential classifications do not result in significantly different group P_ks, or that some group P_ks may be determined by relatively simple modification of results of simulations of other groups. Thus, although no blocks are entirely independent (and all are influenced by mission plans), blocks 4 and 6, and blocks 1 and 2 form two natural groupings for purposes of presentation and discussion in succeeding chapters. Blocks 3 and 5 are considered in Appendices A and B as necessary support items. Such treatment provides the necessary tools to carry out the operations of the remaining blocks 7, 8, and 9. To the extent needed and feasible prior to (1) detailed mission plans, (2) results from pre-test simulations (block 2), and (3) receipt of test data (blocks 3 and 4), the succeeding

chapters and appendices of this paper present the functions of, the procedures for, and the data required by the individual blocks of the flow diagram.[1]

B. PRE-TEST APPROACH

1. Procedures for Engagement Classification (Block 6)

Block 6 achieves classification of all Phase II engagements into a number of groups, each of which consists of many engagements which will have taken place under similar test conditions, so that relatively few simulation runs will need to be made to give representative P_ks for the engagements of each group.[2] The appropriate conditions comprise two broad categories as follows:

(1) Those conditions related to the various ECM test mixes, including offense composition and tactics and defense composition and modes of operation.

(2) The gross geometry conditions (downrange, offset, and altitude) of the engagements.

Mix-related Conditions. The number of groups of ECM mix and mix-related conditions, N_{mix+r}, resulting from the tests depends basically upon the particular missions flown and tactics used, and these are prescribed by the mission plans. N_{mix+r} includes the number, N_{mix}, of "ECM mixes" designated for analysis, as shown in Table 2, augmented by the number N_r of mix-related test conditions (other than engagement geometry)

[1]Since ARM is not considered further in this report, dotted lines are used for the ARM-related blocks in Figure 2. Simulation of ARM is presently feasible only for its post-launch phase; since this is relatively simple, all such ARM engagements can probably be simulated. Thus, classification for ARM-radar engagements in block 6 may be useful primarily as an aid in suggesting pre-launch conditions for use in level 3 evaluation, i.e., for attrition situations where ARM launch conditions were not established and instrumented in the tests.

[2]The economic constraints requiring such classification are discussed in Appendix F of Volume II of WSEG Report 223.

Table 2 (U). MATRIX OF CONTROLLED FACTORS FOR OVERLAPPING FACTORIAL TEST DESIGN SHOWING 9 ECM MIXES ($N_{mix} = 9$)[a]

Support Jamming	ARM	Service Factors[c] \ Scenario[b]	Corridor Chaff: No				Corridor Chaff: Yes			
		On-Board ECM	Yes		No		Yes		No	
			Shallow	Deeper	Shallow	Deeper	Shallow	Deeper	Shallow	Deeper
None	No	Air Force Planning	X	X	X	X	X	X	X	X
			(4)		(1)		(3)		(2)	
		Navy Planning	X	X	X	X	X	X	X	X
	Yes	Air Force Planning	X	X						
			(7)							
		Navy Planning	X	X						
Standoff	No	Air Force Planning	X	X						
			(5)							
		Navy Planning	X	X						
	Yes	Air Force Planning	X	X						
			(8)							
		Navy Planning	X	X						
Escort	No	Air Force Planning								
			(6)							
		Navy Planning	X	X						
	Yes	Air Force Planning								
			(9)							
		Navy Planning	X	X						

NOTE: "X" indicates combinations to be tested.

[a] Mixes (numbers 1-9 in parentheses) are numbered consistent with Table 3.

[b] "Shallow" and "Deeper" describe the depth of penetration of defended area by strike forces for two scenario types to be compared. For engagement simulation purposes, no distinction need be made between Shallow and Deeper engagements--hence the dashed vertical lines.

[c] For engagement simulation purposes, Air Force and Navy strikes are mix-related groups, not ECM mixes--hence the dashed horizontal lines.

which could result in significantly different P_ks.[1] Examples of such mix-related conditions are those resulting from certain aircraft formations, maneuvers, chaff-dispensing aircraft (as distinguished from non-dispensing aircraft in a previously-laid chaff corridor), types of aircraft and SAMs, and (if not standardized for a mix) ECM and ECCM modes (see discussion of Table 3, Chapter IV for further examples).

For any given mission plans, N_{mix+r} could be decreased by permitting greater dissimilarities between the n_{mix+r} engagements within a single group. If a given N_{mix+r} includes all the groups which lead to significantly different P_ks in the tests,[2] and is thus sufficient for level 2 evaluation of test results, it should also include practically all such mix-related groups required for level 3 analysis.[3] The extent to which an equivalent statement for the number (N_{geom}) of different geometry groups would apply might be less, but cannot be determined prior to analyses for level 2 and level 3 evaluations.

---

[1]Where it is unnecessary to make a distinction, the term "mix-related groups" will be used to refer to groups arising from either mixes or mix-related conditions.

[2]It should not be inferred that each of the N_{mix+r} groups, even for the same gross geometry, would always have an incremental range of P_ks not overlapping that of other groups. For example, within a group involving SOJ (see Table 3, Chapter IV, Section A1) there could be quite different P_ks depending upon the relative positions of the target and SOJ aircraft. One of the purposes of the pre-test simulations of block (1) is to devise simple means of determining such P_k differences (not only within, but also between mixes) without having to carry out complete post-test simulations.

[3]Groups resulting from formation size could be an exception; e.g., a formation of three aircraft (which does not appear in the tests and therefore in level 2 evaluation) might be involved in an engagement for level 3 evaluation when one aircraft of a formation of four is shot down.

Geometry Conditions. For each of the N_{mix+r} groups, it would be desirable (if not too costly) to obtain from AFEWES runs a complete three-dimensional grid of P_Ks (downrange, offset, and altitude) of whatever fineness[1] might be required for that group, since this would insure that all gross geometries which might arise in level 3 evaluation would already have been covered.

For a given cost and accuracy in determining P_Ks, tradeoffs exist between the number of mix-related groups N_{mix+r} and the fineness and extent of the three-dimensional grid which affect N_{geom}.[2] For established missions and tactics, the pre-test simulations and analyses of blocks 1 and 2 of Figure 3 are needed to determine whether certain mix-related conditions lead to significantly different P_Ks, and thus constitute separate groups requiring simulation. There also appear to be important instances in which representative P_Ks for some mix-related groups may be obtained by relatively simple operations on the P_Ks of other groups, thus making simulation of the former groups unnecessary. The pre-test simulations considered in Section 2 immediately following are required to validate such concepts, and at the same time investigate typical variations in grid size requirements.

---

[1]Fineness in the downrange dimension can be obtained at less cost by recording (for a given offset and altitude) tracking-error tapes (instead of data for "normal" AFEWES runs), and processing these off-line to obtain miss distances and P_Ks. However, since such processing involves the assumption of zero-error missile tracking (the missile can only be tracked on-line by radar), this procedure is not valid if missile-track jamming (MTJ) is used.

[2]Note that the fineness of the grid required for a constant incremental range of P_K can vary considerably over the grid; it is also a function of the individual mix-related group.

2. Pre-test Validation of Engagement Concepts (Blocks 1 and 2)

Several mix-related engagement conditions are expected to arise whose effects on P_k are not now sufficiently well known to permit a determination of whether or not they should be classified in block 6 as distinct from similar conditions having fewer active elements. For example, it is not certain whether three closely-spaced groups of four noise-jamming aircraft would or would not give significantly different P_ks if more than one group covered the same angle subtended at the radar. Similarly, whether the effect on P_k versus DECM aircraft, when they are covered by more than one (track-while-scan) radar, is sufficient to require separate classification is not known for some conditions. The pre-test simulations address such problems. The more complex situations require extension of AFEWES capacity by modification of normal procedures, as well as some software modifications. Thus, to the extent possible, the pre-test simulations should be designed so that if the results should indicate that separate classifications are required, sufficient information would be obtained to permit approximate scaling factors to be applied (post-test) to the P_ks of the less complex group to obtain those of the more complex group.

Similarly, it appears that representative P_ks for classifications involving either corridor chaff or standoff jamming (which never appear together in a mix) might be more efficiently obtained in block 9 by modification of the P_ks obtained from simulations of other groups, using results obtained from block 1 simulations, rather than by conducting new simulations in block 8 for those two classifications (see, e.g., Chapter IV, Sections B1 and 2).

Other areas for investigation with block 1 simulations which might simplify, speed, or improve confidence in post-test procedures are (1) the savings and compromises involved in using off-line processing of tracking-error tapes when many

missile engagements per flight path are required, (2) the accuracy with which P_ks for evasive maneuvers can be considered to be a function of range only, (3) the determination of major P_k variations for defining grid sizes, and (4) the investigation (where necessary) of mirror-image symmetry of P_ks about the downrange axis. For discussion of further possibilities see Chapter IVB.

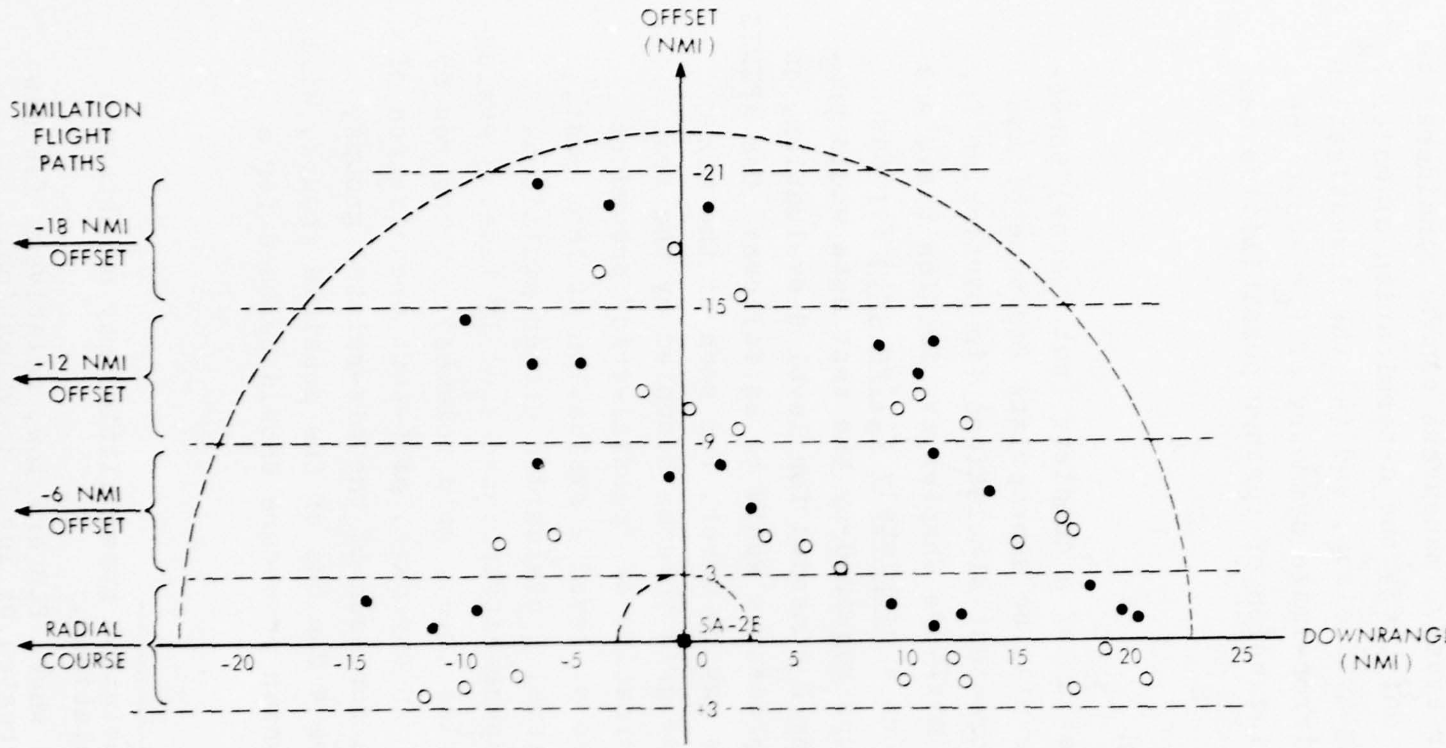
C. POST-TEST APPROACH

Although determination of a complete (but coarse) three-dimensional grid of P_ks will be appropriate for some of the investigations of the pre-test simulations (in particular for the basic on-board ECM mix--see Chapter IV, Section B1a), and (as discussed above) such a completely filled grid for each of the mix-related groups required by the test data would provide practically all the P_ks needed for level 3 evaluation, an alternative post-test procedure would be as follows: Use AFEWES in the most expeditious way to cover, for each of the mix-related groups, only the grid volumes occupied by the test engagements. This alternative or "partial-grid" procedure might serve the purposes of level 2 evaluation at less cost, but would require for level 3 evaluation either additional AFEWES runs or use of space-extrapolated P_ks[1] if level 3 evaluation introduced geometries (i.e., grid volumes) not covered by the test engagements.[2] In any case, post-test organization of intercept-position data for each of the mix-related groups, as illustrated in Figure 4 for one of the possible groups, will be needed in deciding which procedure should be used for a particular group.

---

[1]A feel for some extrapolation possibilities may be obtained from the pre-test simulations.

[2]For successful tactics where P_ks are low, relatively few new engagements would be created by level 3 evaluation.



1. Each black dot represents the mean intercept position of 1-3 missiles of a single salvo (engagement) from the SA-2E at one site. Each open circle serves similarly for the SA-2E at the second site.
2. The dashed semicircles indicate approximate maximum and minimum lethal (horizontal) ranges of the SA-2E for aircraft at 15,000 to 20,000 feet altitude.
3. The dashed lines are the offset grid boundaries assumed for P_k matrices (downrange grid boundaries not shown). AFEWES simulations to obtain representative P_ks for intercepts within each offset grid space (within a bracket) would be run at the average radial or offset course shown under "simulation flight paths".

[a] The Air Force on-board-ECM-only group for close formation with weave maneuvers. If the SAMs had used different tracking, guidance, or ECM modes for any of the engagements shown, the engagements shown probably would have fallen into several mix-related groups.

6-25-74-3

Figure 4 (U). PRESENTATION OF INTERCEPT POSITION DATA (SUCH AS MIGHT RESULT FROM THE PHASE II TESTS) FOR ONE OF THE MIX-RELATED GROUPS[a] VS THE TWO SA-2E SITES. ALTITUDE = 15-20 kft. THE RELATION OF THE DATA TO FLIGHT PATHS TO BE USED IN AFEWES SIMULATIONS FOR P_k MATRICES IS ALSO SHOWN.

Both complete-grid and partial-grid procedures can make use of "tracking-error tape" AFEWES runs instead of normal runs (see Chapter IV, Section B1 for the distinction). The use of normal runs could be less costly for groups having engagements occupying only a few grids, whereas use of tracking-error tape runs is less costly (perhaps by a factor approaching 3, depending upon the fineness of the grid[1]) for a group with engagements occupying a complete grid. Thus the use of both the complete-grid and the partial-grid procedures may be indicated for Phase II post-test simulations as follows:

(1) Use of the complete-grid procedure for a basic group like the on-board ECM group,[2] and for groups which tend to have many engagements widely dispersed. These groups would seem more likely to be needed in level 3 evaluation than would the groups defined in (2) following.

(2) Use of the partial-grid procedure for those groups having only a few engagements, or engagements in only a few grids. Engagements resulting from level 3 evaluation, or from new or altered conditions in the second and third test replications (if initial classification and P_k matrices are based on the first replication to expedite the evaluation schedule) might also produce such groups.

The salvo-intercept positions of Figure 4 were so placed as to suggest that they might tend to occur in groups of three because of the three replications, in the tests, of each mix to be analyzed. A survey of the likely mix-related groups in the tests (Chapter IV, Section A1) indicates that while the on-board-ECM-only mix of Figure 2 is an important one of the

---

[1]As well as upon the determination (by analysis of pre-test simulations--see Appendix C) of the number of tracking-error tape runs (per offset) relative to the number of normal runs (per offset) required to give equivalent statistical significance for resulting P_ks.

[2]Since for some groups the procedures developed in the pre-test simulations of block 1 and analyses of block 2 will permit adjustment of the P_k matrices of this basic group without requiring further simulation.

N_{mix} = 9 basic mix groups, other mix-related conditions and tactics (including types of aircraft and SAMs) give rise to many times this number of groups. If the total number of such groups $N_{mix + r}$ turns out to be large (e.g., as large as a tenth of the total number of test engagements N_e), many of them will consist of very few engagements, and some may have no engagements at all (see Chapter IV, Section A1 for estimates of $N_{mix + r}$ and N_e).

Group diagrams of intercept data (like that of Figure 4) are required to allow selection of (1) the most efficient post-test procedure and type of AFEWES run[1] for the group, and (2) the proper engagement conditions for the run. If there appeared to be unanticipated deviations from group specifications (e.g., if a mixture of two or more ECCM modes were used instead of a prescribed standard mode, or if targets were not covered by chaff when expected to be, etc.), histograms of frequency of occurrence of resulting sub-groups within the group could be considered along with other pertinent factors to decide whether to use separate groups, or the most frequently occurring sub-group, or some weighted average.

To avoid having to classify and simulate incomplete engagements whose P_k is zero,[2] they need be only identified (not classified) from the test data (Table 4, Chapter IV) for level 2 evaluation. When TADBM is used in level 3 evaluations, it will identify the same engagements incomplete that

[1] Whether complete-grid or partial-grid procedure, and whether tracking-error-tape or normal run.

[2] For SAMs, a completed engagement is defined as one in which the target aircraft (or on-board ECM signal) is being tracked at the estimated time of intercept. A SAM engagement is incomplete either because of (1) "Radar Off" command prior to intercept, or (2) breaklock without reacquisition. (The former would be due primarily to ARM launch or command and control decision, the latter to obscuration by chaff or stand-off jamming). All AAA engagements are considered to be completed--either at "Stop Fire", or (since there is no optical tracking) when radar track is broken.

were so identified in the tests (to the extent that it can be made to replicate the tests), and perform the same function for any new engagements introduced, since TADBM determines all "Radar Off" commands, as well as corridor chaff and SOJ obscuration. Thus, if AFEWES simulations for representative groups include completed engagements only, the P_k matrices determined would be appropriate for the TADBM completed engagements as long as they are consistently defined (see Appendix D for further discussion).

The most efficient procedure for obtaining P_k matrices from test data would be to wait until the reduced data required for group classification (block 4 of Figure 3) is available from all completed engagements of all three replications of (Navy or Air Force) test strikes before undertaking group classification. However, time constraints might make it expedient to make an initial group classification and selection of engagement conditions to be simulated (for P_k matrices) based on the first available replication of test strikes, simulating at a later date any additions or changes which might be indicated upon final classification of data from all three replications.

Chapter IV

ENGAGEMENT SIMULATION AND ANALYSIS PLANS FOR SAMS

Section A below gives an illustration of the method of classifying SAM engagements into groups (as discussed in Chapter III), and tabulates the data required to implement this post-test procedure. Section B explains the present plan for the pre-test simulations required to provide missing information needed to carry out such classification, and to minimize the number of groups which require post-test simulation.

A. PROCEDURES FOR SELECTING REPRESENTATIVE GROUPS OF ENGAGEMENTS FOR SIMULATION

The $N_{mix + r}$ groups or classifications of SAM engagements of block 6 of the flow diagram of Figure 3 (Chapter III, Section A) which might be expected to result from the Phase II mission plans (or from the three test replications) are discussed in the first of the following sections. The second section addresses and catalogues the reduced test data and procedures required (for block 4 of the flow diagram) to permit the test engagements to be grouped into such classifications.

1. Classification of Engagement Groups

Table 3 shows potential mix-related groups of Phase II engagements for Air Force strikes. Each of the groups numbered consecutively in the "Number of Offense Groups" column (on right-hand side of top section of the table) requires determination of P_ks with post-test AFEWES simulations (or with other

Table 3. POTENTIAL MIX-RELATED GROUPS FOR PHASE II TESTS (AIR FORCE MISSIONS)

Offense Composition, Tactics[a]		ECM Mixes					
Mission	Formation	Designation[b]	On-board ECM (Self Protection)	Corridor Chaff	Support Jamming	Number of Offense Groups[c]	Applicability[d]
F-4D Strike	Close Formation (4 aircraft)	(1)	------	---	---	1	
		(2)	------	Yes	---	2	CV PG
		(3)	ALQ-119[e] W/O Self Protection Chaff	Yes	---	3	CV PG
			With Self Protection Chaff	Yes	---	4	? CV PG
		(4)	ALQ-119[e] W/O Self Protection Chaff	---	---	5	
			With Self Protection Chaff	---	---	6	? CV
		(5)	ALQ-119[e] W/O Self Protection Chaff	---	ALQ-99	7	CV
			With Self Protection Chaff	---	ALQ-99	8	? CV
	Close Formation (more than four aircraft within +2 beamwidths of tracked aircraft)	(2)	Same as for Corresponding Designations Above			9	CV PG
		(3)				10	CV PG
						11	? CV PG
		(4)				12	CV PG
						13	? CV PG
		(5)				14	CV PG
						15	? CV PG
	Close Formation (weapon delivery maneuver)	(2)	Same as for Corresponding Designations Above			16	CV PG
		(3)				17	CV PG
						18	? CV PG
		(4)				19	
						20	? CV
		(5)				21	CV
						22	? CV
F-4D Aircraft Dispensing Corridor Chaff		(4)	Same as for Corresponding Designations Above			23	(CV)
		(5)				24	(CV)
F-105 IRON HAND	Close Formation (2 aircraft with evasive maneuver)	(7)	ALQ-105[e] W/O Self Protection Chaff	---	---	25	CV
			With Self Protection Chaff	---	---	26	CV
		(8)	ALQ-105[e] W/O Self Protection Chaff	---	ALQ-99	27	CV
			With Self Protection Chaff	---	ALQ-99	28	CV
						28 = Total Number of Offense Groups[f]	

Defense Composition, Modes			ECM Mixes Associated With Each Defense Mode	Number of Groups Associated With Each Defense Mode	Number of Groups Associated With Each Defense Mode / Total Number of Offense Groups	
SAM Type	Mode of Operation					
SA-2B	Manual		(2), (3), (4), (5), (7), (8)	27	27/28	1
	Auto		(1)	1	1/28	
SA-2E	Manual	Mode III	(2), (3), (4), (5), (7), (8)	27	27/28	1
		Mode I	---	0	0	
	Auto	Mode III	---	0	0	
		Mode I	(1)	1	1/28	
SA-3	Manual		(2), (3), (4), (5), (7), (8)	27	27/28	1
	Auto		(1)	1	1/28	
					Over Defense Modes[f] = 3	

[a]It is assumed that missile track jamming (MTJ) is not used. Use of MTJ would require more simulation runs since off-line processing could not be used (see Section B1).

[b]Consistent with test matrix of Table 2.

[c]Cumulative number of groups.

[d]In this column, "?" indicates doubt that the test will include engagements of this group. CV (Concept Validation) indicates that the number of post-test simulations required might be reduced (or possibly eliminated) by the pre-Phase II CV simulations of block 1 of Figure 3, Chapter III. PG (Partial Grid) indicates that few enough engagements may be found in these groups to warrant use of the partial-grid procedure (Chapter III, Section C) whereby post-test replications of complete simulation runs are made only for gross geometries (downrange, offset, and altitude) represented in the test. No entry indicates that post-test replications of simulation runs for complete grids (as defined by block 1 simulations) are probably desirable.

[e]A single mode or preset sequencing of operation during engagement is assumed. Otherwise additional groups for other modes could be required. Similar remarks may be applicable to the mixes which include support jamming.

[f]The product (Total Number of Offense Groups)($\Sigma_{\text{Over Defense Modes}}$) = N_{mix+r} = the maximum number of groups to be simulated (for Air Force only).

procedures developed in pre-test simulations) for certain combinations of SAM defenses and their operating modes shown in the bottom section of the table. The ECM mixes, which involve on-board ECM, corridor chaff, support jamming (SOJ and escort), and ARM, are designated in this table by the same parenthetic numbers (1)-(9) as in Table 2 of Chapter III (numbers (6) and (9), which are associated with escort jamming, do not appear because only the Navy will fly escort missions).

Although mix designation (1) serves as the non-ECM control case for comparison, on-board-ECM-only mixes (4) and (7) are basic mixes for mixes (3)-(6) and (7)-(9), respectively, in the sense that:

(1) They are combined with the remaining mix elements one-at-a-time to form mixes (3), (5), and (6), and mixes (8) and (9), respectively--i.e., either (4) or (7) occurs in all but two of the ECM mixes.

(2) It is possible that mixes (3) and (5) may be obtained from the P_K matrices of (4), and (8) from those of (7) without as many simulations as would be required had P_K matrices not already been obtained for (4) and (7).

The extent to which the second item above can be realized is contingent upon the results obtained from the pre-test simulations of block 1, as indicated by the CV (concept validation) designations in the "Applicability" column.

For each SAM type, the selections illustrated in the bottom section of the table in the column "ECM Mixes Associated with each Defense Mode" (and in the columns to the right of it) assume that against a given mix designation (involving one or perhaps more offensive groups) the same mode of operation is always used.[1] This is why the summation over the defense modes

[1]This assumption causes the table to include only the major modes of defense operation. If other modes (mainly ECCM circuits like FTC, IAGC, lin log receivers, etc.) were not used consistently within these major modes (or groups), this would be taken into account as described in the third-from-last paragraph of Chapter III. The problem could be (continued on next page)

(and over the SAM types) in the last column equals the number of SAM types, i.e., 3. If this assumption is not consistent with defense tactics actually used, i.e., if more than one mode of defense operation were used against a given mix or offense group, the unity figures of the last column would become greater than unity (and sum to more than 3) by the appropriate amounts to properly reflect the increase in N_{mix+r}, the number of representative (or mix and mix-related) groups requiring simulation. N_{mix+r} is the product (Total Number of Offense Groups) ($\Sigma_{\text{Over Defense Modes}}$), i.e., the product of the sums of the right-hand column of the two sections of the table.

If all groups identified in Table 3 are actually realized in the Phase II tests and were to require simulation, and if "conventional" AFEWES procedures[1] were used, then the more desirable post-test approach of obtaining a complete (but coarse) grid of P_ks for each group would involve about (28x3)5 (2x4) = 3,360 "normal" AFEWES runs.[2] (This may be compared with the 5,000 normal runs required for individual simulation of perhaps 1,000 Air Force engagements which Reference 1 roughly estimated might take place in the tests.) Presumably partial or total use of the partial-grid procedure of simulating a group only for grid volumes occupied by test engagements (Section B3,

---

(cont'd) largely avoided if the assumption could be made that AFEWES trackers and Phase II test trackers woule see similar scope pictures and would handle the ECCM circuits the same way.

[1]Whereby 5 replications of a "normal" simulation run (launching successive salvos in real time in a single offset (or radial) and altitude combination) would give intercepts at perhaps 1/2 of the ranges appropriate to a rather coarse grid.

[2]First parenthesis = number of groups N_{mix+r}; second factor = number of normal AFEWES runs per group and per offset (or radial) and altitude pass; last parenthesis covers two passes each over 1 radial plus 3 offset paths at 1 altitude for a rather coarse grid, assuming P_k symmetry about the radial path (two passes may be needed to provide enough salvo intercepts along a given offset or radial path).

Chapter IV) would result in a requirement for appreciably less than 1,000 normal runs[1] (since the last of the above three factors would be reduced, and few or no engagements would occur in some fraction of the groups of the first factor).

Except for MTJ (missile track jamming), either the complete-grid or the partial-grid approach could use "TE tape" runs instead of normal runs (see Section B following). This would eliminate the 2 in the third factor above for the complete-grid approach, and for those partial-grid runs where intercepts over all range grids of a given offset path are required. Further cost benefits which may be achieved from use of TE tape runs are based on the expectation that the pre-test simulations will show that more lower-cost off-line runs can be used with less higher-cost on-line TE tape runs without loss of statistical significance.

If in Table 3 the groups with "?" in the Applicability column indeed do not appear in the tests, then the factor (28x3) in the estimation of the above paragraphs becomes (19x3), providing about 30 percent reduction in number of runs required. This could be offset by changes in tactics or doctrines from those assumed in Table 3 (e.g., use of MTJ, different formations, and other defense modes). Increasing the number of groups (thus giving fewer runs per group) would tend to increase the applicability of the partial-grid procedure (and vice versa).

Finally, although a substantial reduction in the number of post-test simulations required is expected to result from application of the pre-test simulation findings (Section B, below), this cannot be accurately predicted before the findings are available. As soon as mission plans and defense tactics become firm, and pre-test simulation findings are available, more realistic groupings as in Table 3 (as well as diagrams of possible group intercept positions as in Figure 4, Chapter III)

[1]Reference 1 estimated that 1,000 normal AFEWES runs could be carried out for $150,000. However, this figure does not take all associated costs into account.

can be made for both Air Force and Navy strikes. It would then be important to make use of data from the full-system checkout preceding the tests to insure that these group-classifying procedures can be carried through expeditiously with real data. The data required for this are given in Section 2, immediately following.

2. Test-Generated Data Required for Classification of Engagement Groups

The following tabulated data are required in block 4 (Figure 3 of Chapter III) to permit (1) subsequent classification (block 6) of all SAM-aircraft engagements[1] into mix-related groups (illustrated in Table 3), and (2) construction of group intercept-position diagrams (Figure 4 of Chapter III). These two steps will permit selection of simulation conditions for AFEWES runs for representative P_k matrices, using the complete-grid and/or the partial-grid procedures (Section C, Chapter III).

The data listings required for each engagement are given in Table 4. They have been broken down into four categories--engagement identification (4A), geometry-related conditions (4B), mix-related offense conditions (4C), and mix-related defense conditions (4D). Table 5 gives the reduced test data required to obtain the listings of Table 4.

Since sufficient data for classification can be obtained from limited information on test conditions at only two times--time of launch and time of intercept for completed engagements--less data are needed for classification of engagements than are needed for engagement simulation (data for the latter are covered in Appendix B).

[1]With obvious exceptions, the data is also applicable to AAA engagements, as further discussed in Chapter V.

Table 4. DATA LISTINGS (FOR EACH SAM/AAA ENGAGEMENT) REQUIRED TO CLASSIFY ENGAGEMENTS INTO MIX-RELATED GROUPS, AND TO SHOW DOWNRANGE, OFFSET, AND ALTITUDE COORDINATES

A. Engagement Identification

(1) SAM or AAA Type (e.g., SA-2E)

(2) Site Number ____

(3) Engagement Number ____ (in sequence during the strike for each site)

(4) Time of start of engagement hour, minute, second (i.e., time of launch or start fire while an aircraft is being tracked)

(5) Was engagement completed.[a] Yes/No. If No, apparent reason (chaff, SOJ, ARM).

All further listings in Tables 4A-4D refer only to completed engagements (i.e., answer to (5) "yes").

(6) Time of end of completed engagement hour, minute, second, (time of target intercept or stop fire under conditions where target is being tracked)

(7) Radar Track No. ____

(8) Targeted Aircraft Tail Number (Aircraft closest to track position at time of intercept)

(9) Targeted Aircraft Type (e.g., F-4E)

[a]For SAMs, a "completed engagement" is defined as an engagement in which the target aircraft is being tracked at the time of estimated intercept. A SAM engagement may not be completed either because of break-lock without target reacquisition or because of "radar off" prior to intercept. All AAA engagements are considered to be completed--either at "stop fire," or when radar track is broken (see next to last paragraph of Chapter III).

Table 4. (CONTINUED)

B. Geometry-Related Engagement Conditions for Completed Engagements

	At Time of Launch (or Start Fire)	At Estimated Time of Intercept (or Stop Fire)
(1) Targeted Aircraft Position Relative to Site Location (Range, Az, El)		
(2) Estimated Flight Path Direction (Aximuth Angle Relative to True North)		
(3) Targeted Aircraft Position from Site Relative to Estimated Flight Path Direction (downrange, offset)		
(4) Relative Altitude Between Aircraft and Site		
(5) Incremental Locations Relative to Targeted Aircraft Position of All Aircraft jamming on the site frequency within ±2 radar receive beamwidths (narrow dimension) horizontally and vertically[a]	Tail # ΔRng ΔAz ΔEl	Tail # ΔRng ΔAz ΔEl

[a]This will require search within a solid angle window relative to the azimuth-elevation angle of the targeted aircraft. Similar search within about ±7° about the radar pedestal boresight of any other battalion radar with overlapping coverage and in the same frequency band will be required at time of intercept for DECM targets if pre-test simulations show significant degradation of DECM under interference conditions possible in the tests (see Appendix B, Section 3e).

Table 4 (CONTINUED)

C. Mix-Related Offense Conditions for Completed Engagements

	At Time of Launch (or Start Fire)	At Estimated Time of Intercept (or Stop Fire)
(1) Target Aircraft On-Board (Self-protection) ECM operating against Site Radar:		
(a) yes/no		
(b) ECM Equipment Designation		
(c) Frequency of Operation		
(d) Mode of Operation		
(e) Power Output (if available from preflight checkout)		
(2) Jamming from other than target aircraft (C1-2 (5)) operating against site radar for each aircraft (listed sequentially) located within ± 2 receive beam-widths (narrow dimension) about target aircraft angle.		
(a) Tail Number		
(b) ECM Equipment Designation		
(c) Frequency of Operation		
(d) Mode of Operation		
(e) Power Output (if available from preflight checkout)		
(3) Pre-laid Chaff Corridor covering location of target aircraft (yes/no)		
(4) Target Aircraft dispensing self-protection chaff (yes/no)		
(5) Target aircraft in ordnance delivery maneuver (yes/no) ("yes" based on engagement within 20 seconds of the time of ordnance delivery)		
(6) Target aircraft or evasive maneuver (yes/no) ("yes" based on time of engagement after ordnance delivery, if that is the established procedure)		

Table 4. (CONTINUED)

D. Mix-Related Defense Engagement Conditions for Completed Engagements

	At Time of Launch (or Start Fire)	At Estimated Time of Intercept (or End Fire)
(1) Tracking Radar Frequency (S)		
(2) Tracking Radar Mode (automatic, manual)		
(3) For SAM Sites:		
(a) Missile Guidance Mode (1/2 rectified or 3-point)		
(b) Number Missiles Per Salvo		
(c) For SA-2E Sites Operational Mode (TWS or TWS RO)		

Table 5. TEST DATA REQUIRED TO DERIVE LISTINGS OF TABLE 4

DATA ITEM	UNITS AND RANGE OF VALUES
A. TRACKING RADAR	
(1) Site number and type	
(2) Time of missile launches (start fire) with target lock-on	hour, minutes, seconds
(3) Time of missile intercept (stop fire) with target lock-on	hour, minutes, seconds
(4) Time of target "radar offs"	hour, minutes, seconds
(5) Time of target breaklocks	hour, minutes, seconds
Time of target reacquisitions after breaklock (prior to intercept or stop fire)	hour, minutes, seconds
(6) Az,el of angle trking boresight	degrees 0-360, 0-90
(7) Az,el of radar pedestal boresight	degrees 0-360, 0-90
(8) Tracking mode	Auto, manual
(9) Missile guidance mode	1/2 rect., 3-point
(10) Operational mode (SA-2E only)	TWS, TWS RO
(11) Frequency	MHz
(12) Aircraft within chaff	yes/no
B. AIRCRAFT	
(1) Tail Number	number
(2) Function	(descriptive)
(3) Type	(descriptive)
(4) Slant range (Wrt radar)	yards
(5) Azimuth (wrt radar)	degrees, 0-360
(6) Elevation (wrt radar)	degrees, 0-90
(7) Ground speed	feet/sec 0-2000
(8) Est. flight path direction	degrees 0-359
(9) Type formation	(descritpive)
(10) ECM system type	(descriptive)
(11) ECM equipment configuration	(descriptive)
(12) Number ECM pods	number 0-5
(13) ECM pod ID	number 000-0
(14) Missile-track-jam	yes/no
(15) SOJ	yes/no
(16) Escort jamming	yes/no
(17) Transmitter ID	number 000-999
(18) Transmitter frequency	number 000-20,000 MHz
(19) Transmitter bandwidth	MHz 1-500
(20) Transmitter modulation	(descriptive)
(21) Transmitter power	kilowatts (in db)
(22) ECM equipment mode	number 1, 2 or 3
(23) Dispensing chaff	yes/no
(24) Type chaff	(descriptive)
(25) Rate of Dispensing	times per second
(26) Tactic (maneuver)	(descriptive)
(27) Acceleration	feet/sec^2, 0-300
(28) Downrange, offset from radar site relative to estimated flight path direction	yards, yards,
(29) Altitude	feet, 0-100,000

[a]The estimated flight path direction at the time of each engagement could be obtained manually from the aircraft plots and inserted into the data bank for automatic processing. It could also be obtained from RMS track information for a period of 30 seconds prior to launch.

B. PRE-TEST VALIDATION OF ENGAGEMENT SIMULATION CONCEPTS

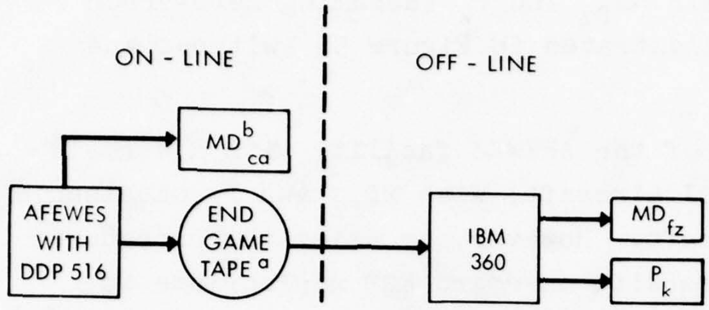
The pre-test AFEWES simulations of block 1 of the flow diagram of Figure 3 in Chapter III are required to verify certain aspects of the proposed simulation approach as discussed in that chapter. In particular, as discussed in Section B2 of that chapter, the simulations should provide information about certain of the N_{mix+r} engagmeent groups (illustrated in Table 3 of Section A1 above) which will then permit increasing the efficiency of simulations for P_k matrices (and miss distances), and decreasing the number of simulations required, while indicating the approximations and limitations introduced.

The first of the following sections identifies and discusses the simulations which now appear to be most appropriate within existing constraints of time and money. The second section discusses further problems and possibilities which will continue to be considered for either pre- or post-test solution as more information is obtained.

1. Plans for Pre-Test Validation of Engagement Simulation Concepts

The tape obtained from that part of the "normal" AFEWES run which is on-line (illustrated to the left of the dashed line in Figure 5A) contains missile and aircraft end-game data required by an off-line (faster than real-time) digital model of fuzing and lethality (to the right of the dashed line) to compute fuze-point (or detonation) miss distance MD_{fz} and kill probability P_k for salvos of up-to-three missiles vs. up-to-four aircraft (in the presence of up-to-three SOJ aircraft).

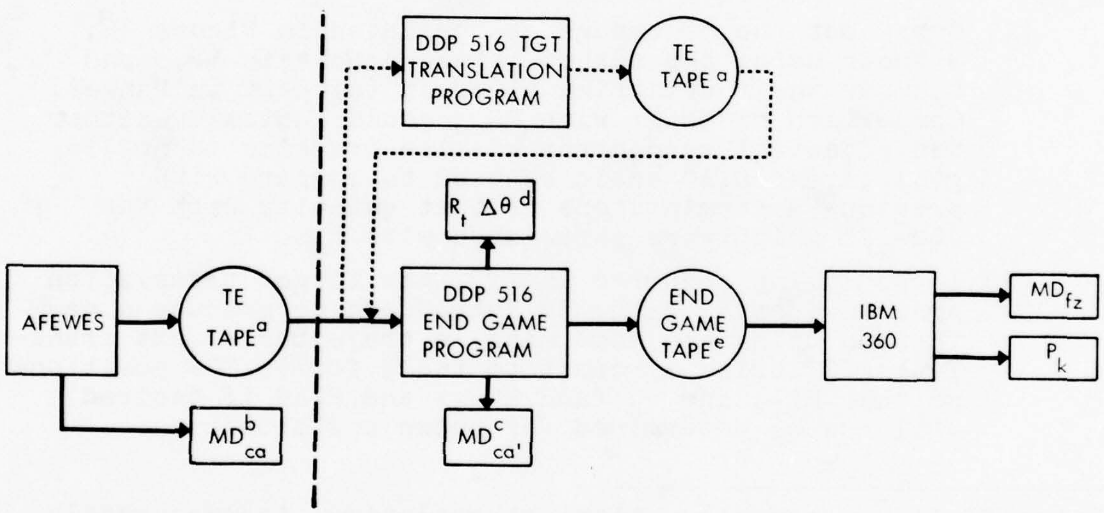
It is not feasible (because of storage problems) to record, during a single on-line run, the end-game tape of a normal run, and a tracking error (TE) tape. However, when many intercepts per offset flight path are required, there is a cost advantage (over a normal run) in recording a TE tape for off-line (real-



a. Records relative end-game orientations and geometries for each missile vs up to 4 aircraft

b. MD_{ca} = miss distance (closest approach) to each of up to 4 aircraft

A. PROCESSING OF END GAME TAPE FOR "NORMAL" AFEWES RUN



a. Records true positions of up to 7 aircraft, plus radar-tracked position

b. MD_{ca} = miss distance (closest approach) to each of up to 4 aircraft

c. $MD_{ca'}$ = miss distance (closest approach) to each of up to 7 aircraft for zero error missile tracking

d. $\Delta\theta$ = angle between tracked direction and true direction of (each of up to 4) aircraft at target range R_t. $(\Delta\theta)^2 = (\Delta\theta_{AZ})^2 + (\Delta\theta_{EL})^2$.
Obtaining $R_t\,\Delta\theta$ would require analysis not now provided by AFEWES.

e. Records relative end-game orientations and geometries for each missile vs up to 4 aircraft

B. PROCESSING OF TRACKING ERROR (TE) TAPE FOR "TE TAPE" RUN

6-25-74-4

Figure 5 (U). BLOCK DIAGRAM OF PROCEDURES FOR TWO TYPES OF AFEWES RUNS

time) processing to obtain MD_{fz} and P_k (assuming zero-error missile tracking), as illustrated in Figure 5B (without the dotted paths).[1]

The capacity limit of the AFEWES facility with a normal run is 4 strike and 3 SOJ aircraft, with MD_{fz} and P_k obtainable only on the strike aircraft. However, by using the procedures of Figure 5B, the 3 SOJs (with on-board ECM appropriate to strike aircraft) may be flown as strike aircraft (without radar cross-section) in a formation of 7, and MD_{fz} and P_k could be obtained for each of the 7 in two steps as follows:

(1) Carry out the procedure as indicated in Figure 3B, without using the dotted paths, to obtain MD_{fz} and P_ks for the four strike aircraft (closest in range). Comparison of $MD_{ca'}$ with MD_{ca} could indicate whether the effect of zero-error missile tracking is negligible,[2] and $R_t\Delta\theta$ could be used to compare with previous determinations of that quantity with the ALQ-126 which were correlated with P_ks.

(2) If no fuzing occurred in (1), the target translation program (dotted path) is introduced to produce a new TE tape using the same missile trajectories but translating 3 strike aircraft to the 3 former SOJ positions so that MD_{fz} and P_k (and $MD_{ca'}$ and $R_t\Delta\theta$ if desired) will now be determined for those positions.

---

[1]This off-line processing, although real-time, is less costly because radars do not have to be manned, and there is less equipment downtime.

[2]For MD_{ca}, the missile-tracking hardware of the radar is required in the loop, whereas only software is involved for MD_{ca}'. Actually, four new strike aircraft positions could be introduced in step (2), but the ECM effects (on the missile trajectories, which are retained in the end-game program) would still be due to only seven aircraft, not eight. With this limitation, repeating step (2) with four new strike positions would allow P_ks to be obtained on multiples of 4 (or fewer) aircraft. The target translation program requires software development which is being accomplished. Without such development, only changes in P_k for the original four strike aircraft could be observed as the number of aircraft with on-board jammers in the formation is increased from 4 to 7.

In the tentative test plan of Table 6 (costs may require some omissions), all runs are TE tape runs (as in Figure 5B) rather than normal runs. Each group of test configurations (bounded by the dashed lines) has different objectives, and includes both Navy and Air Force runs. Manual tracking with 3-point guidance is appropriate to all runs, and each appropriate sub-group is to be done with the SA-2E first in Mode 1, and then in Mode III. With scaling for beamwidths, the trends established for the former should generally apply to the SA-3, and those established for the latter should generally apply to the SA-2B. Brief discussions by group follow. It is obvious that the tactics and modes of operation actually to be used in the tests should be employed in these pre-Phase II simulations if they are to realize maximum post-test utility.

a. Group 1--Basic On-Board ECM Grids, Formation Size Variation, Ratio of On- to Off-Line Processing

As discussed earlier (Section A1), on-board jamming is perhaps the most basic mix. Coarse grids of tracking error, miss distance, and P_k are obtained for the 4-aircraft formations of this group, thus indicating how rapidly these quantities vary along flight paths. The analogous grids obtained for 7-aircraft formations will indicate whether formations of more than four aircraft give appreciably different results.[1]

---

[1]Because of sidelobe rejection and the nature of ECM and ECCM techniques involved, maximum difference might be expected if the 3 additional aircraft are within the same solid angle as the original four. So many different aspects of the formations will be presented that all offsets (or downrange elements) would not need to be covered by the 7 aircraft to demonstrate no appreciable difference. However, if appreciable differences were found, the additional set-up then required to obtain the complete grid for 7 aircraft would make the procedure more costly than it would have been if the complete grid had been obtained originally.

Table 6 (U). TENTATIVE OUTLINE OF SIMULATION TEST PLAN FOR VALIDATION OF EWJT SIMULATION CONCEPTS[a]

GROUP	TC[b]	SERVICE[c]	AIRCRAFT IN FORMATION	ON-BOARD JAMMER[d]	CORRIDOR CHAFF	SOJ (AT 52 NMI)	OFFSET (NMI)	NO. RUNS[e]
1	1	AF	4	ALQ-119	---	---	0	5
	2	AF	4	ALQ-119	---	---	6	5
	3	AF	4	ALQ-119	---	---	12	5
	4	AF	7	ALQ-119	---	---	0	5
	5	AF	7	ALQ-119	---	---	6	5
	6	AF	7	ALQ-119	---	---	12	5
	7	NAVY	4	ALQ-126	---	---	0	5
	8	NAVY	4	ALQ-126	---	---	6	5
	9	NAVY	4	ALQ-126	---	---	12	5
	10	NAVY	7	ALQ-126	---	---	0	5
	11	NAVY	7	ALQ-126	---	---	6	5
	12	NAVY	7	ALQ-126	---	---	12	5
2	13	AF	4	----	$\frac{S}{C}$ = -3 db[f]	---	6	5
	14	AF	4	----	-6	---	6	5
	15	AF	4	----	-9	---	6	5
	16	AF	4	ALQ-119	-3	---	6	5
	17	AF	4	ALQ-119	-6	---	6	5
	18	AF	4	ALQ-119	-9	---	6	5
	19	NAVY	4	ALQ-126	-3	---	6	5
	20	NAVY	4	ALQ-126	-6	---	6	5
	21	NAVY	4	ALQ-126	-9	---	6	5
3	22	AF	4	ALQ-119	---	CONST. BK. LOBE	6	5
	23	AF	4	ALQ-119	---	VAR. BK. LOBE	6	5
	24	AF	4	ALQ-119	---	5° ΔAZ	6	5
	25	NAVY	4	ALQ-126	---	CONST. BK. LOBE	6	5
	26	NAVY	4	ALQ-126	---	VAR. BK. LOBE	6	5
	27	NAVY	4	ALQ-126	---	5° ΔAZ	6	5

[a]All test configurations are to be run vs the SA-2E in manual track with 3-point guidance, for both Mode I and Mode III (the number of runs indicated is for one mode only). Average altitude of aircraft is 18 kft above MSL.

[b]TC = Test Configuration.

[c]F-4 used for Air Force strike aircraft, A-6 and/or A-7 for Navy. If scintillation and vulnerability characteristics are not available for A-7, those of F-4 will be used. SOJ aircraft is the AE-6B EXCAP with ALQ-99 jammer.

[d]In appropriate mode of operation.

[e]All runs to be TE tape runs

[f]At 10 nmi on a radial course.

Some of the data from this group will also be used (as further discussed in Appendix C) to determine whether results (in TE, MD_{fz}, or P_k) using TE tape runs (the procedure of Figure 5B) can provide the same confidence level as those using normal runs (procedure of Figure 5A), while using less of the more expensive on-line runs (but more of the less expensive off-line runs). Although it might appear more efficient to determine this "optimum" ratio of on-line to off-line runs before proceeding to Groups 2 and 3, the necessary delay and interruption of a continuous 2-week schedule of runs might cost more than possible savings.

b. Group 2--Corridor Chaff Parameters

In this group one offset path is run for Navy and Air Force on-board ECM (same ECM as in Group 1), and for no on-board ECM (Air Force only) at 3 signal-to-chaff ratios in order to determine:

(1) The width of the narrow range of signal-to-chaff ratio, $\Delta(S/C)$, expected to result in transition from effective to ineffective chaff.

(2) The magnitude of signal-to-chaff ratio, $(S/C)_{threshold}$, at which such transition occurs.

Above $(S/C)_{threshold}$, P_k should be essentially zero. Below, it should approach results found in Group 1 above for on-board ECM in one case, and results of no-ECM calibrations (routinely run) in the other case (Air Force only).

From this group, it would also be possible to establish the accuracy of operator (or observer) correlation of B-scope appearance with the transition of (2) above. However, this correlation will not be needed if S/C ratios available from TADBM are used to compare with the $(S/C)_{threshold}$ established by (2), as further discussed in Appendix D.

For purposes of this group, no chaff corridors need be delineated (chaff will cover the entire field of the scopes).

c. Group 3--Conditions of SOJ Effectiveness

To test the assumption that SOJ will not be effective when the angle between the radar-SOJ direction and the radar-(target aircraft) direction is equal to or greater than the off-axis angle of the first effective sidelobe maximum of the receiving antenna (in its narrow dimension), a six-mile offset path (as in Group 2) will be used for both Navy and Air Force strike formations with on-board ECM.[1] An SOJ aircraft will be flown at a constant 52 nmi range (1) in a constant average backlobe, (2) in a variable sidelobe structure,[2] and (3)--probably the most stressful case of the three--removed from the radar-target direction by a constant five degrees in azimuth, so that, over the entire flight path of the target, the SOJ will remain in the first effective sidelobe of the azimuth antenna.[3]

---

[1]Note that in the test mixes SOJ is involved only with on-board ECM.

[2]As the SOJ is swept by TWS through the sidelobe structure of the receive beam (requiring AFEWES circuit modification).

[3]This requires special calculation for the SOJ flight path. Note (1) that, for the strike formation to cover the position which stresses the assumption most, intercepts need be carried out only at the extreme lethal range (giving largest J/S ratio), and (2) that, if a radial path were used (giving smaller J/S ratios than the 6 nmi offset except at large range), no special calculation of flight path would be required. However, use of either of these limiting cases (especially the first) would entail the risk than an effect would be observed without any indication of whether it would become negligible for less stressful geometric conditions.

2. Further Candidates for Validation Tests

Should it be possible to conduct tests beyond those included in the outline of Table 4, the following candidates or extensions are being considered. Priorities would be affected by further developments in tactics to be employed. Perhaps some can be done more efficiently post-test.

a. Simulation of appropriate features and conditions of engagements for target delivery maneuver (presumably with on-board ECM). Examination of mission plans and target and site locations might bound the problem.

b. Simulation of appropriate features and conditions of engagements for evasive maneuver by ARM aircraft (presumably with on-board ECM). Because such maneuver may be based on the direction of missile approach, it may be possible to show that the P_K matrix is a function primarily of horizontal range only.

c. The case of b. could be used as a baseline case[1] for investigating possible decrease in DECM jamming efficiency (as evidenced by increased P_Ks) when the jamming aircraft are being illuminated by more than one (TWS) radar (multiple radar environment). This could be done with present facilities subject to the limitation of effectively employing a constant gain antenna for the DECM (variation of interfering signals with inverse square of range, but not with jammer antenna pattern, can be achieved in the required setup).

d. Simulations involving essential features of escort jamming probably should be run when basic tactics are determined.

e. The SOJ simulations of Group 3 of the test plan of Table 6 should eventually be extended to determine P_K matrices (with on-board jamming) for SOJ direction within a main beamwidth about the target direction, using elements of Group 1 as a base case for comparison.

f. Although there is a presumption that P_Ks vs formations of aircraft dispensing corridor chaff will not be significantly altered from those vs the formations

[1] Some other case associated with a larger number of test engagements might be preferrable as a baseline.

were they not dispensing chaff (manual tracking being used in both instances), it would be desirable to demonstrate this. An investigation of the effect of self-protection chaff coupled with evasive maneuver appears to be higher in priority, assuming the tactic will be used. However, in either case, removal of the present limitation of dispersing a total of 14-20 chaff bundles from only one aircraft would require at least a two-month effort to permit sharing the bundles between aircraft in formation and recycling them (previously dispensed bundles would disappear when needed for recycling).

Chapter V

ENGAGEMENT SIMULATION AND ANALYSIS PLANS FOR AAA

A. GENERAL

Essential features of the simulated AAA radars expected to participate in the Phase II Tests were given in Volume II of WSEG Report 223 (Chapter III of Appendix F). It now appears doubtful that any complete Soviet weapon systems will be available. If not, only AAA radar tracking will be simulated in the tests, with no possibility of transitions between radar, optical, and mixed[1] tracking modes, as would normally take place if ECM produced radar-tracking and associated fire control (director) perturbations. Such transitions could be simulated in real time on the AFEWES AAA facility for fire control of the radar-optical director type, with miss distances recorded on-line, and P_Ks determined off-line, for any combination of the tracking modes. Presently AFEWES does not have the type of optical fire control provided by the mechanical, lead-angle computing sight which is normally mounted on the guns. It is now anticipated that only the radar tracking mode will be used (1) in the tests and (2) in simulations for P_K, and this chapter is predicated upon that assumption.[2]

---

[1] Optical angle, radar range.

[2] Draft material has been prepared predicated upon the alternative assumption that AFEWES would determine P_Ks for all tracking modes of the 57 mm gun with FIRECAN and FLAPWHEEL radars and appropriate directors.

B. COMPARISON WITH SAM ENGAGEMENT AND ANALYSIS

Because of the similarity of the ECM-radar aspects of AAA engagements to those of the more numerous and lengthy SAM engagements, many of the simulation procedures discussed for SAMs are directly applicable to AAA. Thus, the AAA equivalent of Table 3 (Chapter IV, Section A1) for classifying the groups of engagements required to be simulated would involve essentially the same group contributions from "Offense Compositon, Tactics" and "ECM Mixes" (upper section of the table). However, the ECM settings (versus conical-scan rather than TWS radars), as well as the relative numbers of engagements in each group, will usually be different. Under "Defense Composition, Modes" (lower section of the table), SA-2B, E, and -3 will be replaced by the AAA systems using FIRECAN, FLAPWHEEL, and GUNDISH. The modes will not include SAM modes I and III, but this does not result in any decrease in the number of groups requiring simulation (assuming SAMs do not use both modes I and III versus the same mix). As with SAMs, MANUAL and AUTO modes in AAA also may be used against the same mix.

Since a probabilistic method based on recorded miss distances is used to determine P_k for the continuous high rate of fire, there is no need for the equivalent of the TE tape runs advocated for obtaining P_ks for SAM salvos closely spaced on an offset flight path (for complete-grid P_k matrices). A representative (fixed length) burst of fire could be a substitute for the SAM salvo as the unit for which P_k is determined. However, in view of the comparatively short duration of AAA engagements, their smaller expected number, and the fact that some post-test simulation "short cuts" analogous to those provided by SAM pre-test simulations would require pre-test reruns for AAA,[1] it appears that AAA P_k determinations should

[1]Although it might be possible in pre-test simulation to handle seven jamming strike aircraft (with software changes, as planned with SAMs), this situation would (continued on next page)

be made for representative lengths of engagements[1] within each mix-related group. The "representative lengths of engagements" would be selected from the AAA equivalent[2] of the group intercept diagrams of Figure 4 of Chapter III. This would be essentially the partial-grid procedure as discussed for SAMs, in that it gives representative rather than complete grid coverage. Any "shortcuts" or concepts transferrable from pre-test SAM simulations would be utilized.

C. VALIDATION WITH HITVAL

Non-ECM validation of AFEWES AAA functions with HITVAL data would appear to be straightforward in concept, involving (1) a comparison of AFEWES tracking errors with those of selected HITVAL tests when AFEWES uses the HITVAL test flight data as input, and (2) comparison of miss distances when AFEWES uses the tracking errors measured in the HITVAL test.[3] Since HITVAL tests the 57 mm gun with FIRECAN only in (1) the computing-sight mode (not available in AFEWES) and (2) the mixed (optical angle, radar range) mode, the validation would have to be in the latter mode, which would not otherwise be used (assuming Phase II

(cont'd) probably occur even less frequently than with SAMs (its importance for SAMs has not yet been established). Candidates a, c, and d for SAM pre-test validation simulations (Section B2 of Chapter IV) have their analogies for AAA radar-ECM interactions; if done for SAMs there would be less need for doing them for AAA.

[1]There is no distinction between completed and incompleted engagements for AAA--engagements begin with "start-fire," and end with "stop-fire" or (since there is no optical tracking) when radar track is broken.

[2]Showing downrange and offset of target aircraft between start-fire and stop-fire, indexed for mean altitude of start and stop fire.

[3]Comparison of miss distances from the same flight paths would give less diagnostic information, but an overall check. The capability for reading in TE tapes required in (2) should be available by late 1974.

excludes optical tracking for AAA). Validation in the radar mode only (to be used exclusively for Phase II evaluation) would be possible for GUNDISH, but it is doubtful that these HITVAL results would be available in time.

D. TEST DATA REQUIRED

The test-generated data required for classification of AAA engagement groups is essentially that listed for SAMs in Chapter IV, Section A2, with appropriate substitutions of AAA for SAM ECCM modes, and substitution of start-fire and stop-fire for missile launch and intercept, respectively.

The non-test-generated data required for post-test AAA engagements is included with that required for SAMs in Appendix A.

The test-generated data required for post-test AAA engagements, not including that required for classification purposes as discussed in the first paragraph above, is included with that required for SAMs in Appendix B.

APPENDIX A

NON-TEST-GENERATED DATA REQUIRED FOR SAM AND AAA ENGAGEMENT SIMULATION

APPENDIX A

NON-TEST-GENERATED DATA REQUIRED FOR SAM AND AAA ENGAGEMENT SIMULATION

The following non-test-generated data and ECM and support equipment of block 3 in Figure 3 of Chapter III is required for SAM and AAA engagements to permit an orderly and expeditious utilization of the AFEWES facility. The data for items A through H should be provided to the Fort Worth Operation of General Dynamics at least six weeks prior to initiation of simulation testing. The data of item I will assist in minimizing any diagnostic or validation problems which may arise during simulation tests. Items D (chaff) and G (optical target model) are not relevant to Phase II post-test simulations as now planned.

A. Aircraft Radar Cross Section (horizontal, vertical and 45°-plane polarizations) in 4°x4° (AZ X EL) increment matrix for (0-360 by 0-90°) for the E/F, G/H, and I-bands.

1. F-4[1]
2. G-105G
3. A-4
4. A-6
5. A-7E
6. EA-6B

B. ECM Antenna Patterns (horizontal, vertical, or circular polarized; transmit and receive) in 4°x4° (AZ X EL) increment matrix (0-360 by 0-90°) for the E/F, G/H, and I-bands, and for installation in appropriate type aircraft of A. above.

---

[1]Data already available at AFEWES.

1. ALQ-119[1]
2. ALQ-105
3. ALQ-100
4. ALQ-126
5. ALQ-99

C. ECM characteristics and descriptions for each ECM equipment (except ALQ-119) in "B" above.

1. General

   a. Block diagram of system
   b. Peak Power (watts)
   c. Frequency Capability (MHz)
   d. Pulse width transmitted (μs)
   e. Duty cycle (%)
   f. Gain (db)
   g. Power requirements and frequency (60 or 400 Hz)
   h. Cooling requirements
   i. Type connectors for RF input and output.

2. Mode Definitions (by Code Number)

   a. Swept Spot Noise
      (1) RF Sweep limits (MHz)
      (2) Spot Width (MHz)
      (3) Sweep Rate (Hz)
      (4) Sweep Function (Sawtooth, Triangle)
      (5) Wobbulation Function Shape (Sawtooth, Triangle)
      (6) Wobbulation Limits (Hz)
      (7) Wobbulation Period (Sec)

   b. Amplitude Modulated Noise
      (1) Noise Bandwidth (MHz)
      (2) AM Function (Square, wave, sine wave)
      (3) Modulation Depth (db)
      (4) Wobbulation shape, limits, period

---

[1]Data already available at AFEWES.

c. Pulse Repeater

(1) AM Function (shape, MOD depth, frequency, wobbulation)

(2) Range Gate Walk-Off (min delay, max delay, function)

(3) Angle Gate Programs (pulse up gate width and timing)

3. ECM Receiver

a. Minimum Detectable Signal (dbm)

b. Thresholds for Identification (dbm)

c. Dynamic Range of Receiver (db)

d. Criteria for Identification (RF, PRF, PW, Scan Timing, Dead Spaces, Amplitude Modulation, etc.)

D. Chaff Characteristics (for each type of chaff to be used)

1. Planned Chaff dispensing programs (ALE-38, ALE-29A, Other?)

2. Chaff Frequency Coverage

3. Growth Functions (up to 10 break points)

a. Range dispersion

b. Azimuth dispersion

c. Elevation dispersion

d. RCS growth (vert, hor and 45° pol.)

4. Drift Rates

a. Altitude (Ft/Min)

b. Azimuth

c. Elevation

Functions of Winds

5. RCS Scintillation

a. Peak-to-Peak amplitude

b. Frequency content.

The above chaff data, plus any test-derived, confirming data (e.g., meteorological data affecting 4.--see also Appendix B, Section 1b and c) are required for the normal method of chaff corridor representation with AFEWES. However, present planning would not require chaff simulation by AFEWES (see Appendix D).

E. For evasive maneuvers, the aircraft positions must be defined as a function of time. (Typically the aircraft turns in a specified direction at some turn rate (or g's) and dives (or climbs) at some rate until a final altitude and heading are reached or for a specified period of time.)

F. Mission Planning Documents

G. An F-4 target model for projection on screen for optical AAA tracking is the only specific aircraft-type model available. There is also a generic model of different (fixed) dimensions. Cost of providing additional models is trivial.

H. BRL Vulnerability Data- The data should include outline drawings of the aircraft with center of gravity identified; vulnerable component identification and location; component vulnerability as a function of fragment size, striking velocity, and striking aspect; kill criteria definition for generating A-Kill and K-Kill data; and blast contours for Kill by overpressure effects. In addition, probabilistic P_k data as a function of miss distance are required for 57-mm and 23-mm AAA projectiles. The aircraft involved are the following:

1. F-4[1]
2. F-105G
3. A-4
4. A-6
5. A-7
6. EA-6B

I. Radar Characteristics of threat radars in flight test.

1. Receiver bandpass (MHz)
2. Antenna Patterns (db vs. deg)
3. Minimum Detectable Signal (dbm)
4. Peak Power (kw)
5. Scan Frequency (Hz)
6. RF (MHz)
7. Pulse Width (μs)

---

[1]Data already available at AFEWES except 57- and 23-mm P_k data.

8. PRF (pps)

9. Squint Angle (deg) for AAA.

J. ECM and support (AGE) equipment with maintenance and operating personnel for the five items listed in B above.

APPENDIX B

TEST-GENERATED DATA REQUIRED FOR SAM AND AAA ENGAGEMENT SIMULATION

APPENDIX B

TEST-GENERATED DATA REQUIRED FOR SAM AND AAA ENGAGEMENT SIMULATION

The following test-generated data of block 5 in Figure 2 (Chapter III), together with the non-test-generated data of block 3 (covered in Appendix A), represent the data inputs required by the procedures of blocks 7 and 8 for engagement simulation. Both this data (Appendices A and B) and the classification data of block 4 given in Chapter IV, Section A2, (with appropriate substitutions for AAA as described in Chapter V), are required to select and conduct post-test simulations. (The classification data of block 4 is a subset of that of block 5.)

Ideally, test-generated data should be at the Fort Worth Operation at least four weeks prior to initiation of simulation testing, with the non-test-generated data already on hand, so that General Dynamics personnel can prepare an AFEWES test plan, generate preprogrammed problem tapes, and initiate necessary setup procedures.

Again chaff data has been included, although present planning may not require use of it in AFEWES post-test simulations. It should be emphasized that while the required type data is listed here, the formidable problem of insuring that the proper data can be readily available in recognizable form for each engagement has not been solved here.

1. Data Related to ECM Mix to be Employed

a. On-Board (self-protection) ECM

(1) Number and types of equipments to be available.

(2) Number and types of equipments to be simulated (with JETS).

(3) ECM modes (pre-flight settings), and mode change logic.

b. Chaff Dispensing Data

(1) Dispensing doctrine and/or program, to include for corridor chaff the number of bundles/second and the beginning and end of the dispensing periods, for self-protective chaff the timing of bursts.

c. Chaff corridor data for normal AFEWES representation (supplementing that of Appendix A, Section D)

(1) Meteorological winds.

(2) Information on dimensions of each separable corridor, and on typical peak-to-peak amplitude and frequency content of chaff scintillation (as could be obtained from analysis of video tapes of test scopes by comparison with AFEWES scopes).

d. Support Jamming

(1) Modes (as a result of operator actions) as a function of time.

(2) Antenna bearing as a function of time.

(3) Transmitted noise bandwidth as a function of time.

(4) RF as a function of time.

2. <u>Data Related to Conditions Existing at Simulated Radar for Each Engagement</u>

a. Track Mode (automatic or manual)

b. Operational mode (I or III)

c. Uplink simulation and/or missile tracking loops requirements

d. Missile guidance mode (1/2-rectified or 3-point)

e. Operational doctrine (to brief radar operators prior to testing)

3. <u>Data Related to Geometric Conditions for Each Engagement</u>

a. Identification of each aircraft by type and ECM loading

b. Position of reference aircraft with respect to radar site (downrange, offset, altitude, velocity, and heading) at time of initial missile launch (or AAA firing)

c. Flight path of reference aircraft as a function of time within ±30 nmi of site.

d. Location of other aircraft in formation with respect to reference aircraft (X,Y,Z) as a function of time

e. Number, types, and locations of interfering radar signals to be supplied to ECM receivers (Chapter IV, Table 4B). The criterion that a radar is providing such a signal is that it have overlapping coverage and be active in the proper frequency band with its pedastal boresight within ±7 degrees of the engaged aircraft at time of intercept.

f. Identification of type of maneuver used, when initiated and when stopped.

APPENDIX C

OPTIMUM USE OF OFF-LINE AFEWES DATA PROCESSING

APPENDIX C

OPTIMUM USE OF OFF-LINE AFEWES DATA PROCESSING

To establish an efficient ratio of on-line TE AFEWES runs[1] to off-line runs[2] for determining SAM miss distance (MD) or kill probability (P_k) to an arbitrary confidence level,[3] consider the example illustrated in Figure C-1A. Taking the five TE replications of a single MI group (the other groups could be used similarly for added statistical weight) gives the cases of missile intercepts illustrated in Figure C-1B (disregard the crosses and circles for the moment).

Tracking errors are random in the vertical direction in Figure C-1 because replications are independent. Tracking errors approach independence in the horizontal direction as their separation in time exceeds their correlation time.[4] Tracking errors affect both intercept MDs and P_ks, as do the remaining (off-line determined) variations in missile flight, fuzing, and

---

[1]On-line runs producing tapes of tracking error (TE) in real time (instead of end game tapes of relative aircraft-missile geometries and orientations, as with "normal" AFEWES runs).

[2]Off-line runs using the TE tapes as inputs.

[3]Assuming missile-track-jamming (MTJ) is not used, and assuming missile tracking error is negligible, since radars on-line are required for missile tracking. The reason for considering this problem is that the cost of the off-line runs is less than that of the on-line runs, so that there is a cost advantage in utilizing this combination instead of normal AFEWES runs when MDs or P_ks are desired for intercepts at many different downranges on a single offset or radial flight path (as will be apparent from consideration of Figure C-1).

[4]For too large a time separation, a region of different MD or P_k may be reached.

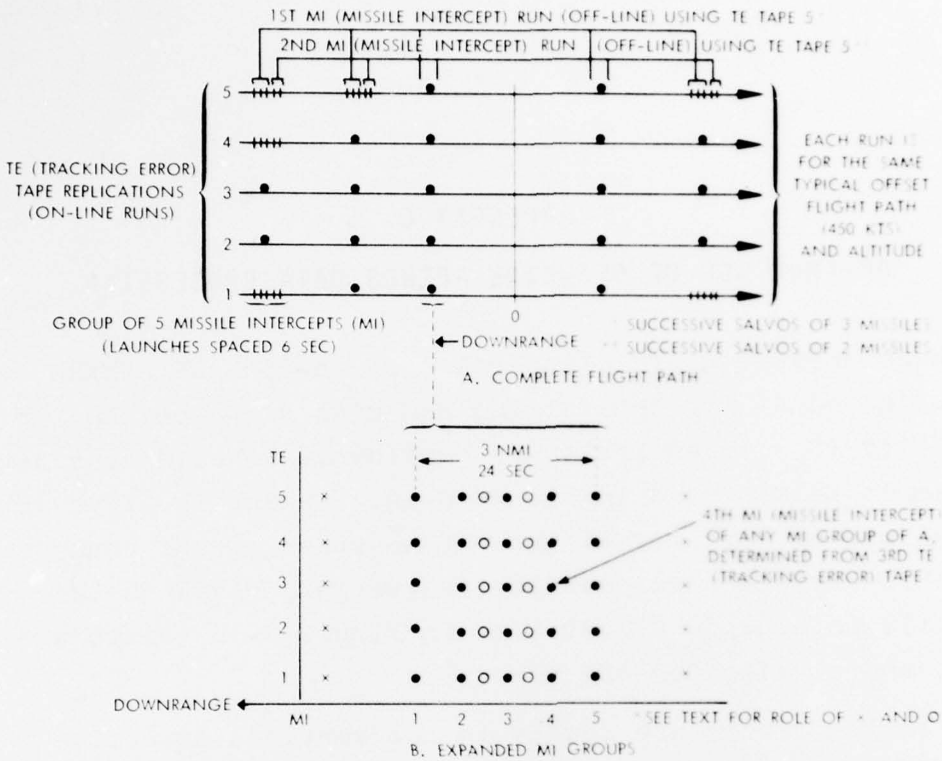


Figure C-1. SCHEMATIC REPRESENTATION OF MISSILE INTERCEPTS WHOSE MISS DISTANCES AND KILL PROBABILITIES ARE DETERMINED BY OFF-LINE PROCESSING OF TRACKING ERROR TAPES

Table C-1. DATA GROUPINGS SUITABLE FOR INVESTIGATING RELATIVE EFFECTS OF TE TAPE AND MI RUNS ON P_K ACCURACY AND VARIABILITY

	Data Groups		MD	σ	P_K	σ	
1	TE_5	MI_5	-	-	-	-	Uses all data.
2	TE_5	$MI_{3(2,3,4)}$	200	50	0.1	0.1	Compare with "conventional" runs.
3	$TE_{1(1)}$	MI_5					
	$TE_{1(2)}$	MI_5					
	•	•					
	•	•					
	$TE_{1(5)}$	MI_5					
		Mean	-	-	-	-	Uses all data.
4	TE_5	$MI_{1(1)}$					
	TE_5	$MI_{1(2)}$					
	•	•					
	•	•					
	TE_5	$MI_{1(5)}$					
		Mean	-	-	-	-	Uses all data.

missile-aircraft relative geometry at burst, which are themselves not entirely independent of tracking error. Since TE runs are more costly than MI runs, it would be desirable to use few of them compared to MI runs if average results were not adversely affected in either bias or variability. A better feel for this might be obtained from examination of the MD's and P_ks and their variances resulting from the data groupings listed in Table C-1 and briefly discussed below.

Data group 1 of Table C-1 averages all the MDs and P_ks for the 25 intercepts of Figure C-1B to give a mean MD and a mean P_k with associated standard deviations which are the best estimates obtainable from the data for the 3-mile extent of the flight path involved. Group 2 uses only 15 missile intercepts,[1],[2] but could be used for direct comparison (since it uses the same number of intercepts) with the average MDs and P_ks provided by the standard 5 replications of normal on-line AFEWES runs. After a similar standard has been selected for TE tape runs (as outlined below), such comparison might be pursued further to determine whether greater concentration of the radar operators on accurate tracking just before they expect intercept in the normal runs will result in higher P_ks for those runs (it will be difficult for the operator to maintain such concentration for the duration of the aircraft flight in the TE tape runs). Any such difference in P_ks would tend to be compensated

---

[1]The $TE_5\ MI_{3(2,3,4)}$ notation indicates use of the intercepts defined by the intersections of all 5 replicated TEs (rows) with the 3 MI positions 2,3, and 4 (columns) in Figure 2.

[2]The MD and P_k with associated σ values shown for Group 2 are rough "visual" averages of results of "normal" AFEWES runs based on Figure F-3 of Appendix F of Vol II of the WSEG/IDA test design. The relatively larger σ of the P_k suggests variability in the fuzing and/or intercept geometry, although it may also be influenced by the non-normal distribution of P_ks. Thus the "optimum" ratio of on-line to off-line runs may be different for MD and P_k.

by the "perfect missile-tracking" in the TE tape runs. The latter tendency could be investigated (in terms of miss distance) by comparison of MD_{ca} and MD_{ca}', as described in Chapter IV, Section B1, in connection with Figure 5. The routine normal runs made for system checkout prior to TE tape runs could be used for such comparisons.

Comparison of the mean MDs and P_ks and their spreads between Groups 3 and 4 (and with group 1) would seem to give the first clue for some judgment as to what extent the separation (horizontally in Figure C-1) of intercepts in time (Group 3) can substitute for separate tracking error runs (Group 4). Depending upon the results of such comparisons, it might then be desirable to conduct a third series of missile intercept (MI) off-line runs like the second one in Figure C-1A except with launches so as to give intercepts placed either like the circles, or like the crosses, in Figure 2. A comparison analogous to that between Groups 3 and 4 would then be made, using the corresponding data Groups (5 and 6) with MIs spaced either 3 seconds (one-half the spacing of Groups 3 and 4) or 12 seconds (twice that of Groups 3 and 4).

Using the interval between MIs found most appropriate, final comparisons (if justified by the statistical significance of previous results) would involve selected combinations of (approximately) 25 intercepts, using appropriate numbers (other than 5 and 1 already tested) of the rows and columns of Figure 2B.

APPENDIX D

PROCEDURES FOR SIMULATING THE EFFECTS OF CORRIDOR CHAFF

APPENDIX D

PROCEDURES FOR SIMULATING THE EFFECTS OF CHAFF

A. NORMAL AFEWES PROCEDURES FOR SIMULATING CHAFF

For prelaid chaff corridors, the AFEWES chaff simulator provides noise-like scintillations of specified amplitude (related to radar cross-section) and frequency content, scaling properly with dispersion (growth) and drift rates, and with range,[1] for flexible initial volume boundaries and conditions. There is also provision for simulating chaff (given velocities and time of dispensing, and growth and drift rates) beginning with the dispensing of the individual chaff packages, as from the ALE-38 or 29A, or from rocket ejection. Presently this is limited to dispensing a total of 20 bundles (from 10 bursts per second to 10 seconds per burst) from a single aircraft.

This type simulation for corridor chaff has general applicability and flexibility, but it is difficult to determine (for prelaid corridors) whether the dynamic and meterological input parameters which must be supplied (Appendix A, Section D) will result in proper matching of actual chaff test conditions, which also are expected to be variable and difficult to determine. "Closing the loop" to compare the corridor shapes and qualities generated in simulation with those of the test corridors (and

[1]The conventional variation of target signal with inverse fourth power of range does not apply to chaff signals when radar beamwidths are smaller than chaff dimensions, as is usually the case (except for one dimension only of fan beams). Thus the range variation of chaff signals with the 3A-2E in mode I is usually different from that in mode III.

adjusting input parameters for agreement) would involve a correlation exercise between simulation-recorded and test-recorded video scope tapes (and other related data) not likely to be feasible with the time and effort available.

B. PLANNED PROCEDURES FOR SIMULATING EFFECTS OF CHAFF

1. Corridor Chaff

In lieu of the impractical "closed loop" approach discussed above, chaff-related statistics (such as the mean and standard deviation of obscuration times during engagements, and the probability distribution of times between launch and obscuration, both as functions of downrange and offset coordinate grids) might be obtained by post-test analysis of pertinent data collected in the tests (and/or from post-test review of video tapes of B scopes), for each mix-related group involving corridor chaff. These statistics might then be applied to AFEWES simulations for the groups without modeling chaff in the normal manner (of Section A) by assuming (1) that P_k is unaltered when the statistics (Monte Carloed) do not give obscuration at intercept, and (2) that $P_k = 0$ when they do (in essence, assumptions (1)-(4) of the following paragraph). Perhaps the chaff statistics need not be considered different for different groups; even so, there may not be sufficient data for complete-grid P_k matrices, and in any case, the associated post-test effort would be large.[1] Thus, the method would seem more complex and less

[1]With this "statistical" method, since engagements in corridor chaff would be simulated by AFEWES in such manner as to include "incomplete" engagements in the resulting P_k matrices, no test engagements with obscuration by chaff at time of intercept should be recorded as incomplete in the classification data (Table 4, Chapter IV), nor should TADBM exclude such incomplete chaff engagements if it uses such matrices in level 3 evaluation (see following paragraphs). Otherwise incomplete chaff engagements will be included twice.

suited to the tight post-test schedule than that discussed in the remaining paragraphs of this Appendix.

Since TADBM makes use of a chaff program (similar to that of AFEWES) which determines signal-to-chaff (S/C) ratios for all radars in the IADS, the most practical procedure for Phase II now appears to be one which (1) makes use of what test data will be available to more closely relate the inputs for the TADBM chaff program to the actual test conditions, and which (2) is based on the following assumptions (See Figure D-1):

(1) The major effect of corridor chaff (when it is effective) is to prevent launch. Thus a major part of the effectiveness of chaff will be evidenced outside the engagement by fewer launches (and perhaps fewer "Radar Ons").

(2) There is a narrow range of signal-to-chaff ratio, $\Delta(S/C)$, above which tracking is characteristic of the situation without chaff, and below which break-lock occurs.

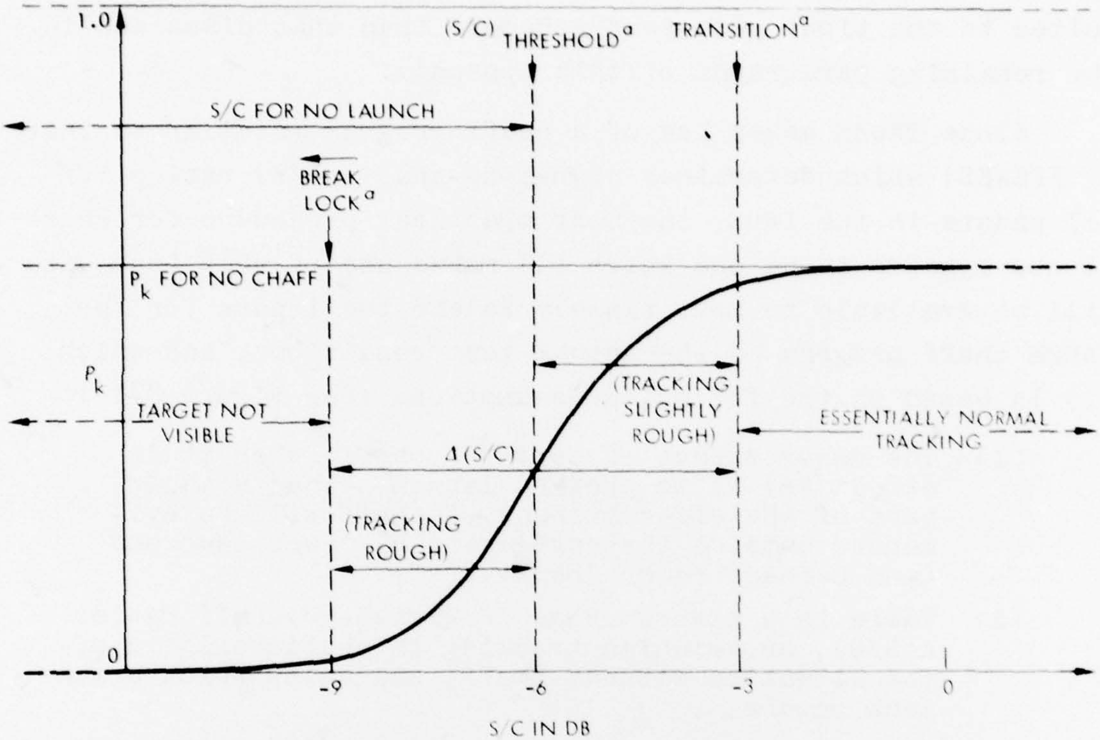
(3) When the signal-to-chaff ratio S/C is greater than the value $(S/C)_{threshold}$ at the mid-point of $\Delta(S/C)$, use of P_ks for the test conditions (or mix-related group) which would have existed without chaff (at estimated time of intercept) is a satisfactory approximation for evaluation purposes.

(4) When $\Delta(S/C)$ is less than $(S/C)_{threshold}$, $P_k = 0$ is a satisfactory approximation.

(5) $(S/C)_{threshold}$ is a constant value which can be determined (as can $\Delta(S/C)$ by pre-test simulations with AFEWES.

Thus, for level 3 evaluation, TADBM would determine S/C at estimated time of intercept, compare with $(S/C)_{threshold}$, and select the appropriate AFEWES P_k matrix[1] if $S/C > (S/C)_{threshold}$, or select $P_k = 0$ if $S/C < (S/C)_{threshold}$.

[1] The appropriate matrix is one in which incomplete engagements were excluded from simulation of the appropriate group without chaff (as in Table 4, Chapter IV, Section A1). Note that stand-off jamming may be treated as an obscuration problem (with incomplete engagements) in an analogous fashion, provided it proves to be effective only in the main beam.



[a] This is an average, not a discrete value.

7-30-74-1

Figure D-1. ASSUMED EFFECTS OF SIGNAL-TO-CHAFF RATIO (S/C) ON P_K

No post-test simulation runs with corridor chaff (or with corridor chaff statistics) would be required on AFEWES.

For level 2 evaluation, TADBM need not be used. The matrix as defined in footnote 1, page D-3, is still appropriate. It is realized since incomplete engagements due to chaff have been excluded from classification data (Table 4, Chapter IV), and those due to "Radar Off" are automatically excluded by the tests (as they are by TADBM for level 3 evaluation). Actually, in view of assumption (1) above, such meticulous care in selecting the appropriate P_k matrix may have relatively little effect on the results of the overall evaluation.

2. Self-Protection Chaff

The primary purpose of dispensing chaff for self-protection (after detection of missile launch) is to force the SAM to use manual tracking instead of the more accurate automatic tracking. It is doubtful that the chaff further degrades manual tracking (or the salvo P_ks) to an appreciable extent. Self-protective chaff probably will not be used with on-board noise jamming, but it probably will be used with DECM and maneuver. Again, for the latter case, the primary effect of the chaff versus SA-2 and 3 type SAMs would seem to be to insure manual tracking, although more thorough investigation of this would be desirable. No pre-test AFEWES runs with self-protection chaff are presently planned.